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ENTRANCE HEAD AND DISCHARGE HEAD IN PIPES

...BY...

Carroll Carson Wiley

THESIS FOR THE DEGREE OF BACHELOR OF SCIENCE
IN CIVIL ENGINEERING

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This is to certify that the following thesis, prepared under the direction of Professor A. N. Talbot, Head of the Department of Municipal and Sanitary Engineering, by CARROLL CARSON WILEY, entitled ENTRANCE HEAD AND DISCHARGE HEAD IN PIPES, is accepted by me as fulfilling this part of the requirement for the degree of Bachelor of Science in Civil Engineering.

Ira O. Baker.

Head of the Department of Civil Engineering

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Entrance Head and Discharge Head in Pipes.

It is a well established hydraulic fact that the shape and condition of the entrance or inlet into a pipe affects the discharging capacity. Conical or bell-shaped inlets have a larger discharging capacity than plain cylindrical inlets and, conversely, the loss of head at entrance, for a pipe discharging a given amount, varies with the shape of the inlet, being less for a conical or bell-shaped mouthpiece. Experimenters who revealed these facts also made experiments with similar mouthpieces on the discharge end and found that when flowing full the discharging capacity was greatly increased or, in other words, that for the same discharge the total head lost was greatly reduced. (See Merriman's "Treatise on Hydraulics", 1903 Edition, Page 137) An examination of these experiments reveals, however, that all were made with small pipes varying in diameter from $\frac{1}{2}$-in. to 2-in., until in 1903 Mr. W. P. Ireland made a series of experiments at the University of Illinois using 6-in. and 12-in. pipes. He showed that the same laws of flow apply to these sizes as to the smaller and further established the value of conical inlets. In order to obtain low heads and still maintain the pipe flowing full he submerged the 6-in.

pipe and made a few tests in that manner. He found that for high velocities the discharge of the pipe when submerged was the same as when discharging freely but that under low heads the discharging capacity was considerably greater than for a pipe discharging freely since the latter would not flow full at the discharge end.

Since there appears to be little data relating to the effect of conical mouthpieces on the discharge end of a pipe and the value of these mouthpieces has not been put into numerical form, also as the entrance loss of a pipe flowing full with low velocities has not been thoroughly investigated it is thought that an experimental investigation of these questions may be of some value both practically and theoretically.

Before entering into the investigation, however, it may be well to briefly review the theoretical principles of flow through pipes and explain the new terms introduced into the equations.

Flow Through Pipes.

The total head which causes flow of water through pipes is absorbed in three ways viz.:- (1) by imparting velocity to the water, (2) by overcoming the resistance of friction, (3) by the resistance of the inner edge

of the pipe, contraction of the stream, and the expansion to full section again just inside the pipe, together known as entrance head. These conditions may be represented by the equation, $h = \frac{v^2}{2g} + f\frac{l}{d}\frac{v^2}{2g} + m\frac{v^2}{2g}$ in which h is the total head causing flow, $\frac{v^2}{2g}$ is the amount of h used to impart velocity to the water, $f\frac{l}{d}\frac{v^2}{2g}$ is the loss due to friction and $m\frac{v^2}{2g}$ is the amount of the entrance head. In these terms v is the average actual velocity of the water through the pipe in feet per second, g is the acceleration of gravity, f is the coefficient of of friction, l is the length of the pipe in feet, d is its diameter in feet and m is the coefficient of entrance loss. $\frac{v^2}{2g}$ is usually referred to as the "velocity head."

The loss due to friction in a short pipe is small as shown by the following demonstration. In an experiment with a 6-in. pipe, 22½-in. long, a head of 0.75 ft. gave a velocity of 5.48 feet per second. The velocity head corresponding to this is 0.47 ft. The water after contraction fills the pipe at about two diameters from the end, say 10½-in. in this case. Then $l = 1.0$ and $d = 0.5$. The friction factor $f = 0.022$ (See Merriman's "Treatise on Hydraulics", 1903 Edition, Page 168). Substituting these values, $f\frac{l}{d}\frac{v^2}{2g} = 0.022 \times \frac{1.0}{0.5} \times 0.47$ $= 0.0206$ ft. The loss due to friction in this case is then about 4.4%. Nevertheless the term $f\frac{l}{d}\frac{v^2}{2g}$ will be dropped for pipes of about

three diameters' length, the loss due to friction being included in the term for entrance head $m\frac{v^2}{2g}$. That is, the general form of formula that will be used is $h = (1+m)\frac{v^2}{2g}$. It may be added that it is the usual practice to include the friction loss of the first three diameters' length of pipe in the coefficient of entrance head.

In the above review the ordinary expression for entrance head $m\frac{v^2}{2g}$ has been used, m being obtained from $m = (\frac{1}{C^2} - 1)$ (see Merriman's "Treatise on Hydraulics", 1903 Edition, Art. 13 Page 165) in which C is the coefficient of discharge obtained by dividing the actual discharge of the short pipe by the theoretical discharge $a\sqrt{2gh}$, a being the area of the cross section of the pipe in square feet. Since it has been shown that the shape and condition of discharge end affects the discharging capacity it is thought best to introduce a term to express this. It may be considered that the discharge mouthpiece utilizes a part of the head existing in the velocity of the water through the pipe. Calling the head utilized in this way $n\frac{v^2}{2g}$ and the entrance head $m\frac{v^2}{2g}$, the combined effect of entrance head and discharge head is then $(m-n)\frac{v^2}{2g} = m'\frac{v^2}{2g}$ where m is the coefficient of entrance head and n the coefficient of discharge head. Then m' is the coefficient of combined entrance and discharge head and equals $(m-n)$. Then, as before, $m' = (\frac{1}{C^2} - 1)$ or $(m-n) = (\frac{1}{C^2} - 1)$

The real problem is, therefore, to determine separate values of m and n. In order to do this a number of experiments were made with a 6-in. pipe about $3\frac{1}{2}$ diameters long projecting into both inlet and discharge chambers and submerged to obtain low heads. From these experiments the coefficients of discharge c were determined by dividing the actual discharges by the theoretical. These values were then inserted in $(m-n) = \left(\frac{1}{c^2} - 1\right)$ to determine values of $(m-n)$. Assuming now that a plain cylindrical discharge end does not affect the discharging capacity whatever, or in other words, that all the velocity head is lost — all experiments bearing out this assumption — then n for a cylindrical discharge end becomes zero and $(m-n)$ reduces to m and a value of the coefficient of entrance head has been determined. In this manner the value of m for any kind of a mouthpiece may be obtained. Now by placing a mouthpiece on the discharge end of the pipe n can be readily determined by obtaining the value of $(m-n)$ by experiment. Then with the m previously determined and $m-n$ known, n is easily computed. In this way values of n for all shapes of mouthpieces may be obtained. If now a mouthpiece be placed on both the inlet and discharge ends of the pipe and $(m-n)$ determined by experiment the value so obtained should approximately equal the

difference of m and n for the given mouthpieces as obtained above. The experiments show this to be true. Similar comparisons might well be made for pipes with flush ends.

Experiments with 6-in. Pipe.

For these experiments a cylindrical cast iron pipe 22½-in. long bored accurately to a 6-in. calibre was used. The pipe had threads cut on each end and was provided near the middle with a flange containing bolt holes (see Plate I). Six diverging mouthpieces with threads cut in them to fit the pipe were were provided. These mouthpieces each made a different angle of divergence with the axis of the pipe and were of such a length that the area of the larger end was twice that of the pipe. The pipe was placed in a horizontal position protruding through the water-tight partition which divided a water-tight box into two compartments. The water discharged from the box through two vertical rectangular openings, the flow being equally distributed vertically and the level of the water in the box maintained at any desired height by means of baffle boards placed over the openings. The difference of level in the compartments of the box, which is the head on the pipe, was obtained by two methods.

First, by means of two vertical glass tubes, one to each compartment. The tubes connected to the inside of the box near the bottom and the height of water in them showed the height in the box. A meter stick reading to millimeters was placed beside each tube and the readings made on these, then $h = h_1 - h_2$. This method was used for heads greater than 0.10 ft. Second, for the low heads a differential gauge was used. This was connected to the box at the same points as the above glass tubes by means of rubber tubing and was provided with a scale reading to 0.005 ft. A mixture of carbon tetrachloride and gasoline having a specific gravity of 1.25 was used in this gauge thus multiplying the actual head by four and hence reducing the probable error.

The water discharging from the box was measured in a circular pit below 7.995 ft. in diameter and 5.0 ft. in depth. The rise of the water in the pit was indicated by means of a float in the water to which was attached an iron rod carrying a pointer which moved along a level rod graduated to feet, tenths and hundredths.

A set of experiments was made with each mouthpiece separately and also with combinations of mouthpieces, the discharge end as well as the inlet end having mouthpieces on it. A set comprised readings with the pipe under from five to ten different heads each experi-

ment being repeated as a check. The water discharging from the box was first conveyed by means of a waste pipe to a waste pit until the difference of level in the two compartments of the box became constant. The waste pipe was then withdrawn and the time of entrance of the water into the measuring pit obtained from a watch. After allowing the water in the pit to rise a convenient height the stream was again diverted by means of the waste pipe and the time of diversion noted. The rise of water was measured with the float described above, the rod being read to the nearest 0.01 ft. Knowing the diameter and hence the cross-section of the pit, the rise of the water in feet and the time in seconds the actual discharge in cubic feet per second was computed.

In making these experiments the rise of water in the pit was read to the nearest 0.01 foot, the probable variations in readings being less than 0.005 ft. The greatest error from this cause would then occur when the smallest head, 0.39 ft., was read. This would give a maximum error of 1.28%.

To get the diameter of the pit the mean of thirty measurements was taken. These diameters were measured by means of a special measuring rod graduated to feet, tenths and hundredths and carrying a vernier reading to thousandths. The inaccuracy of measure is, therefore, very small. The mean dia-

meter was 7.995 ft. The largest variation from this at any height was 8.003 hence the maximum error due to inaccuracies of cross-section is probably less than 0.1%

To obtain the head on the pipe the rods were read to the nearest millimeter or 0.003 ft. The largest error was then when the smallest head, 0.10 ft. was read, this may be 3.0%. For heads less than 0.10 ft. the differential gauge was used and read to the nearest 0.005 ft. This, when reduced would give a maximum error in the actual head of 0.0005 ft. The maximum error with the differential gauge was when the lowest head 0.008 ft. was read. This may reach 6.0%

For taking the time an ordinary watch was used and read to the nearest second. It was found that the waste pipe was shifted in much less than $\frac{1}{2}$ second and that the time could easily be taken to $\frac{1}{2}$ second. This may give an error of $\frac{1}{2}$ second which in case of the shortest time taken, 60 seconds, would give a maximum error of 0.83%.

Combining the different opportunities for error and remembering that in no one experiment did all these conditions of maximum error exist and also that the square root of the head and not the head itself appears in the results it is believed that for the lowest heads the possible error in the final results may reach 4.0% and is probably

less than 1.0%

The results of the experiments performed as above described are given in Table 1 following together with the theoretical discharge Q, the coefficient of discharge c and the coefficient of combined entrance and discharge head m' or (m-n). The theoretical discharge was calculated from the equation $Q = a\sqrt{2gh}$ in which Q is the theoretical discharge in cubic feet per second, a the cross-section of the pipe in square feet, g the acceleration of gravity and h the total head causing flow, for a 6-in. pipe this reduces to $Q = 1.574\sqrt{h}$. The coefficient of discharge was obtained by dividing the actual discharge q by the theoretical discharge Q. i.e. $c = \frac{q}{Q}$. The coefficient of combined entrance and discharge head m' or (m-n) was obtained from $m' = (\frac{1}{c^2} - 1)$ The mean velocity of the water through the pipe was calculated from the equation $q = av$ or $v = \frac{q}{a}$ where v is the velocity in feet per second, q the actual discharge in cubic feet per second and a the cross section of the pipe in square feet.

Plates and Tables.

The results of the experiments are given in Table 1, together with the theoretical discharge Q, the coefficient of discharge C and the coefficient of loss m' or (m-n).

Table 2 gives values of (m-n), m and n as derived from the experiments.

Table 3 gives mean values of (m-n) for 0.7 feet per second velocity and for velocities greater than 3.0 feet per second.

Table 4 shows the amount of reduction in m' due to the use of mouthpieces as compared with a plain cylindrical pipe.

Table 5 gives values of m for the different mouthpieces at different velocities.

Table 6 gives values of n for the different mouthpieces at different velocities.

Table 7 is a comparison of the values of (m-n) for combinations as obtained by direct experiment and as obtained from the separate values of m and n.

Plate 1 is a sketch of the pipe used in the experiments.

Plate 2 shows the mouthpieces used.

Plates 3 to 19, inclusive, are curves platted from Table 1 using velocities v as abscissas and (m-n) as ordinates. Mr. Ireland in 1903 found that for a pipe discharging freely and discharging submerged the values of m were practically the same.

Therefore, for the conditions where no mouthpieces were used on the discharge end, so that $(n-n) = m$, points have been platted from Mr. Ireland's data, the points being designated by triangles to distinguish them from the results of these experiments which are shown by circles.

Plates 20 to 30, inclusive, are curves platted from Table 4 showing the reduction in m' due to mouthpieces, as compared with a plain cylindrical pipe.

Plates 31 to 36, inclusive, give values of n for the different discharge mouthpieces.

Plate 37 is a diagram showing the variation ~~in~~ in m' for different angles of divergence of the mouthpieces. The reduction in m' as compared with a plain cylindrical pipe is also shown.

Plate 38 is a diagram showing the variations in n for different angles of divergence of discharge mouthpieces.

Conclusions.

From the data given the following deductions may be made:-

(1) For velocities through the pipe greater than 1.5 to 2.0 feet per second the value of m or (m-n) remains practically constant for any given condition of inlet and discharge ends.

(2) As the velocity decreases below 1.5 to 2.0 feet per second the values of m or (m-n) increase. No satisfactory explanation has yet been made of this phenomenon for a pipe flowing full at the discharge end.

(3) The values of m for diverging inlets of from 10° to 30° divergence and with velocities greater than about 2.0 feet per second do not differ greatly and 0.18 may be taken as the mean value. For angles of divergence greater than 30° m increases slowly being 0.28 for a 60° inlet. 0.25 may be taken as a mean value.

(4) The values of n for diverging discharge mouthpieces and velocities greater than 2.0 feet per second differ greatly for different angles of divergence. The values rise rapidly from zero for a cylindrical outlet to an angle of divergence of 10° then decrease more slowly till a divergence of 30° is reached beyond which they are nearly constant and practically zero.

(5) For velocities below 2.0 feet per second n varies slightly but is nearly the same as for the higher velocities.

(6). The amount of velocity head utilized by a diverging discharge mouthpiece as compared with a plain cylindrical inward projecting pipe is nearly constant for all velocities. Likewise, the reduction in m' [$(m-n)$] due to the addition of an inlet mouthpiece or by a combination of inlet and discharge mouthpieces is nearly constant for all velocities.

(7) The greatest discharging capacity is obtained by using both an inlet and a discharge mouthpiece, the value of $(m-n)$ for the combination being nearly the same as the difference of the m and n for the given mouthpieces as obtained separately. A combination of a 10° discharge mouthpiece with a 30° inlet mouthpiece appears to be most efficient having a coefficient of discharge of about 1.20 or a value of $(m-n)$ of -0.30.

(8) Since the larger end of the mouthpieces has twice the area of the pipe, the velocity at the end must be $\frac{1}{2}$ of that in the pipe and hence the velocity head is $\frac{1}{4}$ as great. Therefore the maximum amount of velocity head which can, theoretically, be utilized by a discharge mouthpiece is 75% of that in the pipe or, in other words the greatest value of n theoretically possible is 0.75 The the greatest value obtained in these experiments was 0.50 with the 10° mouthpiece which shows great efficiency. Mouthpieces of these relative dimensions were used since

they are capable of practical application to pipes of large size and it was desired to find their efficiency.

These experiments, while not numerous, are believed to be quite accurate. Among the more inaport conclusions derived from this investigation is the large gain to be derived by placing mouthpieces with small angles of divergence on the discharge ends of pipes, (especially for the higher velocities). Also that mouthpieces relatively short as compared with the diameter of pipe show considerable efficiency. The field of research however is by no means exausted and there remain yet many interesting problems to be investigated.

TABLE 1.

1	2	3	4	5	6	7	8	9	10	11.
Ref. Nº	Mouthpiece		Head on Pipe.	Time in	Rise in Pit.	Actual Discharge q	Theo. Disch'ge Q	Average Actual Velocity V	Coef-ficient of Discharge	Coef-ficient of Loss
	Inlet End.	Dis-charge End.	Feet	Seconds	Feet	Cubic Feet per Second	Cubic Feet per Second	Feet per Second	C	(m-n)
1	0°	0°	0.015	300	0.78	0.131	0.193	0.67	0.68	1.16
2			0.016	300	0.80	0.134	0.199	0.68	0.675	1.20
3			0.020	150	0.47	0.158	0.222	0.81	0.71	0.98
4			0.225	200	2.32	0.583	0.748	2.97	0.78	0.645
5			0.227	150	1.74	0.583	0.751	2.97	0.78	0.645
6			0.351	200	2.89	0.728	0.932	3.72	0.79	0.605
7			0.415	200	3.17	0.794	1.015	4.05	0.785	0.625
8			0.742	150	3.13	1.028	1.360	5.26	0.77	0.69
9			0.750	150	3.20	1.073	1.363	5.48	0.79	0.605
10			0.035	160	0.72	0.225	0.295	1.15	0.765	0.71
11			0.035	180	0.80	0.223	0.295	1.14	0.755	0.76
12			0.030	180	0.74	0.207	0.273	1.06	0.76	0.74
13			0.070	150	0.96	0.322	0.417	1.64	0.77	0.69
14			0.066	120	0.75	0.313	0.405	1.60	0.775	0.67
15			0.086	160	1.14	0.359	0.462	1.83	0.78	0.645
16			0.089	160	1.16	0.365	0.470	1.86	0.78	0.645
17			0.125	180	1.54	0.43	0.555	2.20	0.775	0.67
18			0.125	150	1.30	0.436	0.555	2.23	0.785	0.625
19			0.056	180	1.03	0.288	0.372	1.47	0.77	0.69
20			0.021	300	1.00	0.168	0.228	0.86	0.735	0.86
21	10°	0°	0.009	300	0.63	0.106	0.148	0.54	0.715	0.955
22			0.010	310	0.74	0.120	0.157	0.61	0.765	0.71
23			0.015	250	0.82	0.165	0.193	0.84	0.855	0.37
24			0.015	250	0.84	0.167	0.193	0.85	0.865	0.34
25			0.060	250	1.70	0.343	0.383	1.77	0.90	0.24

1	2	3	4	5	6	7	8	9	10	11
26	10°	0°	0.060	240	1.59	0.344	0.383	1.77	0.90	0.24
27			0.210	200	2.62	0.660	0.722	3.37	0.915	0.195
28			0.224	200	2.68	0.678	0.745	3.46	0.91	0.21
29			0.257	200	2.90	0.730	0.798	3.73	0.915	0.195
30			0.250	190	2.71	0.728	0.787	3.71	0.925	0.17
31			0.510	150	3.09	1.037	1.126	5.29	0.92	0.18
32			0.488	150	3.05	1.026	1.102	5.24	0.93	0.16
33			0.581	1.60	3.49	1.100	1.200	5.61	0.92	0.18
34			0.557	150	3.23	1.088	1.174	5.55	0.93	0.16
35	0°	10°	0.009	180	0.38	0.106	0.148	0.54	0.715	0.955
36			0.008	180	0.38	0.106	0.141	0.54	0.75	0.78
37			0.038	150	0.81	0.272	0.307	1.39	0.89	0.26
38			0.155	100	1.18	0.592	0.620	3.03	0.955	0.10
39			0.157	210	2.44	0.584	0.624	2.98	0.935	0.145
40			0.353	100	1.77	0.888	0.937	4.53	0.95	0.11
41			0.358	140	2.48	0.890	0.943	4.55	0.945	0.12
42			0.400	100	1.89	0.948	0.997	4.84	0.95	0.11
43			0.424	100	1.91	0.960	1.028	4.940	0.935	0.145
44			0.648	100	2.43	1.225	1.265	6.25	0.97	0.065
45			0.617	100	2.35	1.180	1.235	6.02	0.955	0.10
46	15°	0°	0.011	210	0.55	0.132	0.165	0.67	0.80	0.57
47			0.010	320	0.80	0.126	0.157	0.64	0.805	0.55
48			0.054	200	1.31	0.330	0.366	1.68	0.90	0.24
49			0.060	200	1.36	0.342	0.382	1.75	0.895	0.25
50			0.063	200	1.37	0.344	0.394	1.76	0.875	0.31
51			0.316	270	4.10	0.762	0.885	3.88	0.86	0.35
52			0.276	210	3.15	0.752	0.827	3.83	0.91	0.205
53			0.254	150	2.16	0.722	0.794	3.68	0.91	0.205
54			0.740	150	3.73	1.248	1.355	6.39	0.92	0.18
55			0.767	130	3.35	1.295	1.380	6.62	0.94	0.14.

1	2	3	4	5	6	7	8	9	10	11
56	0°	15°	0.010	360	0.88	0.123	0.157	0.63	0.785	0.62
57			0.011	360	0.94	0.131	0.165	0.67	0.795	0.58
58			0.036	120	0.65	0.272	0.298	1.39	0.91	0.21
59			0.039	120	0.67	0.282	0.314	1.44	0.90	0.24
60			0.087	200	1.62	0.407	0.466	2.07	0.875	0.31
61			0.089	200	1.69	0.424	0.470	2.16	0.90	0.24
62			0.254	150	2.17	0.727	0.794	3.71	0.915	0.195
63			0.254	150	2.17	0.727	0.794	3.71	0.915	0.195
64			0.445	120	2.31	0.968	1.050	4.95	0.92	0.18
65			0.402	100	1.85	0.930	0.998	4.75	0.93	0.16
66			0.765	100	2.51	1.260	1.375	6.43	0.92	0.18
67			0.765	100	2.48	1.250	1.375	6.38	0.91	0.21
68	15°	15°	0.011	180	0.53	0.149	0.165	0.76	0.905	0.22
69			0.011	180	0.53	0.149	0.165	0.76	0.905	0.22
70			0.034	120	0.70	0.293	0.293	1.49	1.00	0.00
71			0.033	120	0.69	0.289	0.288	1.47	1.005	0.00
72			0.043	200	1.36	0.343	0.326	1.75	1.05	−0.09
73			0.069	200	1.79	0.450	0.415	2.30	1.085	−0.15
74			0.069	220	1.98	0.452	0.415	2.31	1.085	−0.15
75			0.299	150	2.81	0.940	0.862	4.80	1.09	−0.16
76			0.317	70	1.39	1.000	0.887	5.10	1.13	−0.215
77			0.346	150	3.00	1.002	0.936	5.10	1.075	−0.13
78			0.311	150	2.84	0.952	0.878	4.86	1.08	−0.145
79			0.595	120	3.26	1.365	1.215	6.20	1.125	−0.21
80			0.495	100	2.53	1.273	1.110	5.67	1.150	−0.235
81	20°	0°	0.008	300	0.70	0.117	0.141	0.60	0.83	0.45
82			0.008	300	0.71	0.119	0.141	0.60	0.845	0.40
83			0.020	240	0.98	0.205	0.223	1.05	0.92	0.18
84			0.060	240	1.68	0.352	0.385	1.79	0.915	0.195
85			0.138	120	1.28	0.538	0.585	2.75	0.92	0.18

1	2	3	4	5	6	7	8	9	10	11
86	20°	0°	0.230	120	1.68	0.704	0.755	3.60	0.935	0.145
87			0.235	120	1.68	0.705	0.764	3.60	0.92	0.18
88			0.432	120	2.29	0.960	1.035	4.90	0.925	0.17
89			0.420	100	1.92	0.965	1.020	4.92	0.93	0.16
90	0°	20°	0.011	300	0.84	0.141	0.165	0.72	0.855	0.37
91			0.011	300	0.85	0.141	0.165	0.72	0.855	0.37
92			0.029	305	1.44	0.237	0.268	1.21	0.88	0.295
93			0.029	120	0.56	0.235	0.268	1.20	0.875	0.305
94			0.060	180	1.25	0.349	0.385	1.78	0.905	0.22
95			0.060	120	0.84	0.352	0.385	1.79	0.91	0.20
96			0.112	150	1.40	0.470	0.527	2.40	0.895	0.25
97			0.112	150	1.41	0.473	0.527	2.42	0.90	0.24
98			0.185	120	1.44	0.604	0.677	3.08	0.895	0.25
99			0.186	120	1.43	0.600	0.680	3.06	0.88	0.295
100			0.495	90	1.84	1.030	1.108	5.26	0.93	0.16
101			0.505	120	2.38	0.998	1.120	5.09	0.885	0.275
102	30°	0°	0.014	180	0.55	0.154	0.186	0.78	0.83	0.46
103			0.014	180	0.56	0.157	0.186	0.80	0.845	0.40
104			0.040	120	0.67	0.282	0.314	1.44	0.90	0.24
105			0.042	120	0.68	0.285	0.322	1.45	0.89	0.265
106			0.082	200	1.60	0.405	0.460	2.07	0.88	0.29
107			0.082	200	1.60	0.405	0.460	2.07	0.88	0.29
108			0.390	120	2.17	0.906	0.985	4.62	0.92	0.18
109			0.390	120	2.17	0.906	0.985	4.62	0.92	0.18
110			0.390	100	1.82	0.914	0.985	4.67	0.93	0.16
111			0.385	150	2.65	0.890	0.977	4.55	0.915	0.195
112			0.613	100	2.32	1.163	1.233	5.93	0.945	0.12
113			0.630	100	2.36	1.185	1.253	6.05	0.945	0.12
114	30°	30°	0.009	180	0.40	0.112	0.148	0.57	0.76	0.73
115			0.009	180	0.41	0.115	0.148	0.58	0.775	0.67

1	2	3	4	5	6	7	8	9	10	11
116	30°	30°	0.036	120	0.64	0.268	0.300	1.37	0.895	0.25
117			0.036	120	0.65	0.272	0.300	1.39	0.905	0.22
118			0.097	200	1.74	0.437	0.490	2.23	0.89	0.26
119			0.096	170	1.47	0.434	0.487	2.22	0.89	0.26
120			0.373	100	1.77	0.888	0.963	4.58	0.925	0.17
121			0.373	150	2.71	0.906	0.963	4.62	0.94	0.13
122			0.452	100	1.98	0.995	1.060	5.41	0.935	0.15
123			0.478	120	2.43	1.010	1.090	5.57	0.935	0.15
124			0.748	90	2.30	1.280	1.360	6.53	0.94	0.13
125			0.736	100	2.51	1.253	1.350	6.42	0.93	0.16
126	45°	0°	0.009	180	0.40	0.112	0.148	0.57	0.76	0.73
127			0.009	180	0.39	0.109	0.148	0.56	0.74	0.83
128			0.050	120	0.70	0.293	0.350	1.49	0.84	0.42
129			0.106	200	1.79	0.450	0.512	2.30	0.88	0.29
130			0.102	200	1.72	0.442	0.503	2.25	0.875	0.31
131			0.326	150	2.42	0.810	0.898	4.14	0.90	0.24
132			0.323	130	2.05	0.792	0.895	4.04	0.885	0.275
133			0.558	120	2.60	1.086	1.176	5.54	0.92	0.18
134			0.563	90	1.93	1.075	1.182	5.50	0.91	0.21
135			0.855	100	2.65	1.330	1.450	6.79	0.92	0.18
136			0.845	80	2.11	1.323	1.445	6.75	0.92	0.18
137	0°	45°	0.011	300	0.70	0.117	0.165	0.60	0.71	0.99
138			0.010	300	0.66	0.110	0.157	0.56	0.705	1.02
139			0.058	120	0.70	0.293	0.378	1.49	0.775	0.67
140			0.115	200	1.68	0.422	0.534	2.15	0.79	0.605
141			0.115	200	1.65	0.413	0.534	2.11	0.775	0.67
142			0.527	100	1.81	0.908	1.140	4.63	0.80	0.57
143			0.524	100	1.80	0.905	1.140	4.62	0.795	0.59
144			0.922	100	2.41	1.210	1.510	6.18	0.80	0.57
145			0.887	100	2.35	1.180	1.485	6.02	0.795	0.59

1	2	3	4	5	6	7	8	9	10	11
146	45°	45°	0.011	380	0.96	0.127	0.165	0.64	0.77	0.69
147			0.011	280	0.70	0.126	0.165	0.64	0.765	0.72
148			0.044	120	0.66	0.276	0.332	1.41	0.83	0.45
149			0.107	200	1.78	0.447	0.515	2.28	0.865	0.34
150			0.109	200	1.79	0.450	0.520	2.30	0.865	0.34
151			0.330	120	1.94	0.811	0.905	4.14	0.895	0.25
152			0.343	120	1.97	0.824	0.923	4.21	0.89	0.26
153			0.442	100	1.94	0.973	1.045	4.96	0.93	0.16
154			0.490	100	1.99	0.995	1.113	5.08	0.895	0.25
155			0.828	80	2.12	1.330	1.435	6.79	0.925	0.17
156			0.828	100	2.59	1.300	1.435	6.64	0.905	0.22
157	0°	60°	0.010	300	0.62	0.104	0.157	0.53	0.665	1.26
158			0.011	300	0.68	0.114	0.165	0.58	0.68	1.16
159			0.060	120	0.67	0.282	0.383	1.44	0.74	0.83
160			0.052	120	0.63	0.264	0.360	1.34	0.73	0.86
161			0.145	180	1.68	0.468	0.599	2.38	0.78	0.64
162			0.148	180	1.68	0.468	0.605	2.38	0.775	0.67
163			0.502	120	2.09	0.875	1.117	4.46	0.77	0.69
164			0.498	120	2.09	0.875	1.113	4.46	0.785	0.63
165			0.875	110	2.57	1.170	1.452	5.98	0.805	0.55
166			0.875	100	2.33	1.170	1.452	5.98	0.805	0.55
167	60°	60°	0.010	300	0.66	0.111	0.157	0.57	0.705	1.02
168			0.011	300	0.70	0.117	0.165	0.60	0.71	0.99
169			0.017	150	0.41	0.151	0.203	0.77	0.74	0.82
170			0.112	120	1.09	0.455	0.527	2.32	0.86	0.36
171			0.109	100	0.90	0.451	0.517	2.30	0.875	0.31
172			0.112	60	0.54	0.451	0.527	2.30	0.865	0.34
173			0.436	120	2.19	0.918	1.040	4.68	0.885	0.28
174			0.428	90	1.64	0.915	1.030	4.66	0.89	0.265
175			0.887	100	2.65	1.330	1.482	6.78	0.895	0.25

} omit

1	2	3	4	5	6	7	8	9	10	11
176	60°	60°	0.840	90	2.29	1.285	1.440	6.56	0.895	0.25
177	20°	10°	0.008	240	0.65	0.136	0.141	0.69	0.97	0.07
178			0.008	180	0.47	0.132	0.141	0.67	0.94	0.13
179			0.030	200	1.22	0.306	0.273	1.56	1.12	-0.20
180			0.023	150	0.71	0.238	0.239	1.22	1.00	0.00
181			0.022	150	0.72	0.242	0.233	1.23	1.04	-0.075
182			0.072	120	1.15	0.482	0.422	2.46	1.145	-0.235
183			0.069	120	1.15	0.482	0.414	2.46	1.165	-0.26
184			0.192	100	1.61	0.810	0.690	4.14	1.17	-0.27
185			0.164	120	1.70	0.715	0.637	3.65	1.12	-0.205
186			0.496	120	3.14	1.310	1.110	6.80	1.18	-0.28
187			0.322	160	3.24	1.010	0.883	5.16	1.15	-0.245
188	30°	10°	0.011	240	0.88	0.184	0.165	0.94	1.12	-0.205
189			0.011	180	0.64	0.179	0.165	0.91	1.08	-0.14
190			0.034	185	1.24	0.337	0.290	1.72	1.16	-0.26
191			0.035	120	0.80	0.336	0.294	1.72	1.14	-0.23
192			0.033	150	0.95	0.318	0.286	1.63	1.11	-0.19
193			0.066	180	1.65	0.462	0.404	2.36	1.145	-0.235
194			0.063	200	1.83	0.460	0.395	2.35	1.165	-0.26
195			0.303	90	1.84	1.030	0.868	5.27	1.19	-0.29
196			0.302	120	2.50	1.046	0.865	5.33	1.21	-0.315
197			0.186	120	1.94	0.813	0.678	4.15	1.20	-0.305
198			0.185	120	1.95	0.817	0.677	4.16	1.21	-0.315
199			0.501	80	2.17	1.360	1.116	6.95	1.22	-0.33
200			0.498	100	2.71	1.360	1.114	6.95	1.23	-0.335

TABLE 2.

Values of (m-n), m and n.

Mouthpiece		V = 0.7			V = 1.0			V = 1.5			V = 2.0			V = 3.0			V = 4.0			V = 6.0		
Inlet End.	Disch'ge End.	(m-n)	m	n	(m-n)	m	n	(m-n)	m	n	(m-n)	m	n	(m-n)	m	n	(m-n)	m	n	(m-n)	m	n
0°	0°	1.06	1.06	0.0	0.82	0.82	0.0	0.68	0.68	0.0	0.64	0.64	0.0	0.63	0.63	0.0	0.62	0.62	0.0	0.62	0.62	0.0
10°	0°	0.56	0.56	0.0	0.36	0.36	0.0	0.22	0.22	0.0	0.20	0.20	0.0	0.18	0.18	0.0	0.18	0.18	0.0	0.18	0.18	0.0
0°	10°	0.68	1.06	0.38	0.36	0.82	0.46	0.18	0.68	0.50	0.13	0.64	0.51	0.12	0.63	0.51	0.12	0.62	0.50	0.12	0.62	0.50
15°	0°	0.54	0.54	0.0	0.36	0.36	0.0	0.22	0.22	0.0	0.19	0.19	0.0	0.18	0.18	0.0	0.17	0.17	0.0	0.17	0.17	0.0
0°	15°	0.56	1.06	0.50	0.38	0.82	0.44	0.22	0.68	0.44	0.20	0.64	0.44	0.20	0.63	0.43	0.20	0.62	0.42	0.20	0.62	0.42
20°	0°	0.40	0.40	0.0	0.26	0.26	0.0	0.20	0.20	0.0	0.20	0.20	0.0	0.20	0.20	0.0	0.20	0.20	0.0	0.20	0.20	0.0
0°	20°	0.46	1.06	0.60	0.32	0.82	0.50	0.24	0.68	0.44	0.22	0.64	0.42	0.22	0.63	0.41	0.22	0.62	0.40	0.22	0.62	0.40
30°	0°	0.50	0.50	0.0	0.34	0.34	0.0	0.24	0.24	0.0	0.20	0.20	0.0	0.18	0.18	0.0	0.18	0.18	0.0	0.18	0.18	0.0
0°	30°	1.10	1.06	-0.04	0.83	0.82	-0.01	0.66	0.68	0.02	0.61	0.64	0.03	0.59	0.63	0.04	0.58	0.62	0.04	0.58	0.62	0.04
45°	0°	0.66	0.66	0.0	0.50	0.50	0.0	0.34	0.34	0.0	0.28	0.28	0.0	0.24	0.24	0.0	0.24	0.24	0.0	0.24	0.24	0.0
0°	45°	0.92	1.06	0.14	0.74	0.82	0.08	0.64	0.68	0.04	0.61	0.64	0.03	0.59	0.63	0.04	0.58	0.62	0.04	0.58	0.62	0.04
0°	60°	1.06	1.06	0.0	0.88	0.82	-0.06	0.74	0.68	-0.06	0.67	0.64	-0.03	0.62	0.63	-0.01	0.60	0.62	0.02	0.60	0.62	0.02
15°	15°	0.22	0.54	0.50	0.06	0.36	0.44	-0.10	0.22	0.44	-0.14	0.19	0.44	-0.16	0.18	0.43	-0.16	0.17	0.42	-0.16	0.17	0.42
30°	30°	0.56	0.50	-0.04	0.36	0.34	-0.01	0.22	0.24	0.02	0.18	0.20	0.03	0.16	0.18	0.04	0.16	0.18	0.04	0.16	0.18	0.04
45°	45°	0.68	0.66	0.14	0.50	0.50	0.08	0.34	0.34	0.04	0.30	0.28	0.03	0.28	0.24	0.04	0.26	0.24	0.04	0.26	0.24	0.04
60°	60°	0.82	0.82	0.0	0.62	0.54	-0.06	0.44	0.37	-0.06	0.36	0.31	-0.03	0.30	0.30	+0.01	0.28	0.28	0.02	0.28	0.28	0.02
20°	10°	0.12	0.40	0.38	-0.06	0.26	0.46	-0.18	0.20	0.50	-0.22	0.20	0.51	-0.24	0.20	0.51	-0.24	0.20	0.50	-0.24	0.20	0.50
30°	10°	0.08	0.50	0.38	-0.12	0.34	0.46	-0.24	0.24	0.50	-0.26	0.20	0.51	-0.30	0.18	0.51	-0.30	0.18	050	-0.30	0.18	0.50

TABLE 3.

MEAN VALUES OF (m-n).

Mouthpiece		Coefficient of Loss (m-n)	
Inlet End	Discharge End	$V = 0.7$	$V > 3.0$
0°	0°	1.06	0.62
10°	0°	0.56	0.18
0°	10°	0.68	0.12
15°	0°	0.54	0.17
0°	15°	0.56	0.20
15°	15°	0.22	− 0.16
20°	0°	0.40	0.20
0°	20°	0.46	0.22
30°	0°	0.50	0.18
30°	30°	0.56	0.16
45°	0°	0.66	0.24
0°	45°	0.92	0.58
45°	45°	0.68	0.26
60°	0°	—	0.28
0°	60°	1.06	0.60
60°	60°	0.82	0.28
20°	10°	0.12	− 0.24
30°	10°	0.08	− 0.30

TABLE 4.

REDUCTION IN m' BY USING MOUTHPIECES.

Compared with a Plain Cylindrical Pipe.

Mouthpiece		Reduction in m'							
Inlet End.	Dischge End.	V=0.7	V=1.0	V=1.5	V=2.0	V=3.0	V=4.0	V=5.0	V=6.0
10°	0°	0.50	0.46	0.46	0.44	0.45	0.44	0.44	0.44
0°	10°	0.38	0.46	0.50	0.51	0.51	0.50	0.50	0.50
15°	0°	0.52	0.46	0.46	0.45	0.45	0.45	0.45	0.45
0°	15°	0.50	0.44	0.44	0.44	0.43	0.42	0.42	0.42
15°	15°	0.84	0.76	0.78	0.78	0.79	0.78	0.78	0.78
20°	0°	0.66	0.56	0.48	0.44	0.43	0.42	0.42	0.42
0°	20°	0.50	0.50	0.44	0.42	0.41	0.40	0.40	0.40
30°	0°	0.56	0.48	0.44	0.44	0.45	0.44	0.44	0.44
0°	30°	-0.04	-0.01	0.02	0.03	0.04	0.04	0.04	0.04
45°	0°	0.40	0.32	0.34	0.36	0.39	0.38	0.38	0.38
0°	45°	0.14	0.08	0.04	0.03	0.04	0.04	0.04	0.04
45°	45°	0.38	0.32	0.34	0.34	0.35	0.36	0.36	0.36
0°	60°	-0.00	-0.06	-0.04	-0.03	0.01	0.02	0.02	0.02
60°	60°	0.24	0.20	0.24	0.28	0.33	0.34	0.34	0.34
20°	10°	0.94	0.88	0.86	0.86	0.87	0.87	0.87	0.87
30°	10°	0.98	0.94	0.92	0.90	0.93	0.92	0.92	0.92
30°	30°	0.50	0.46	0.46	0.46	0.47	0.46	0.46	0.46

TABLE 5.

VALUES OF m FOR INLET MOUTHPIECES

Mouth-piece	Coefficient of Entrance Head, m.					
	V = 0.7	V = 1.0	V = 1.5	V = 2.0	V = 3.0	V = 6.0
Cylindrical	1.06	0.82	0.68	0.64	0.63	0.62
10°	0.56	0.36	0.22	0.20	0.18	0.18
15°	0.54	0.36	0.22	0.19	0.18	0.17
20°	0.40	0.26	0.20	0.20	0.20	0.20
30°	0.50	0.34	0.24	0.20	0.18	0.18
45°	0.66	0.50	0.34	0.28	0.24	0.24
60°	—	—	—	—	—	*0.28

* Ireland.

TABLE 6.

VALUES OF n FOR DISCHARGE MOUTHPIECES.

Mouth-piece	Coefficient of Discharge Head n.					
	V = 0.7	V = 1.0	V = 1.5	V = 2.0	V = 3.0	V = 6.0
Cylindrical	0.0	0.0	0.0	0.0	0.0	0.0
10°	0.38	0.46	0.50	0.51	0.51	0.50
15°	0.50	0.44	0.44	0.44	0.43	0.42
20°	0.60	0.50	0.44	0.42	0.41	0.40
* 30°	-0.04	-0.01	0.02	0.03	0.04	0.04
45°	0.14	0.08	0.04	0.03	0.04	0.04
60°	0.0	-0.06	-0.04	-0.03	0.01	0.02

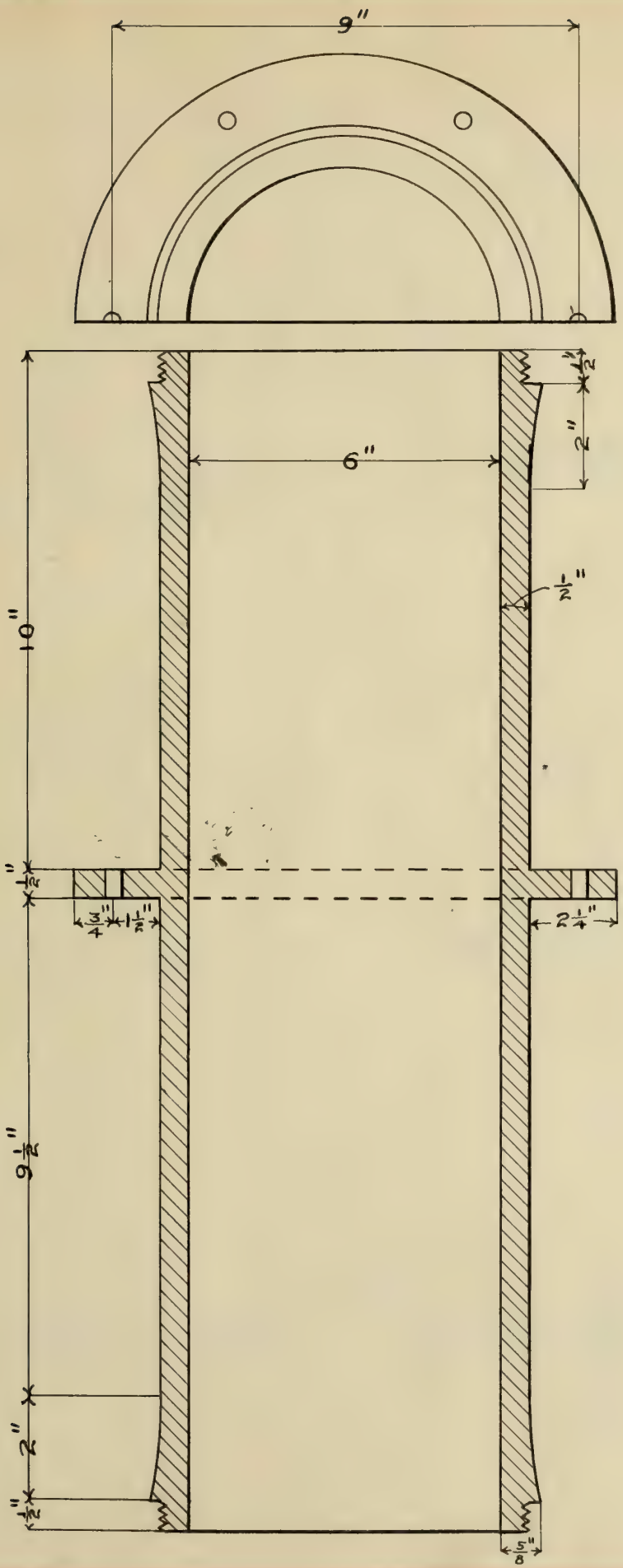
* Computed

TABLE 7.

COMPARISON OF VALUES OF (m-n) FOR COMBINATIONS.

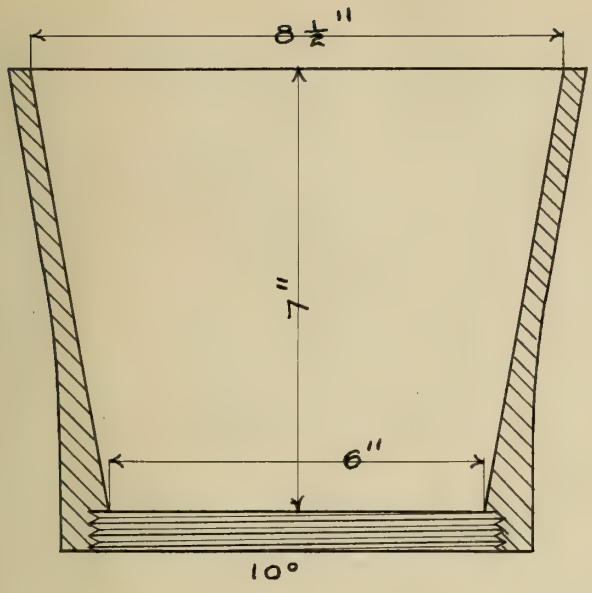
Combination		VALUES OF (m-n)											
		V = 0.7		V = 1.0		V = 1.5		V = 2.0		V = 3.0		V = 6.0	
Inlet End.	Dischge End.	from Tables 5 and 6	from Table 2	from Tables 5 and 6	from Table 2	from Tables 5 and 6	from Table 2	from Tables 5 and 6	from Table 2	from Tables 5 and 6	from Table 2	from Tables 5 and 6	from Table 2
15°	15°	0.04	0.22	-0.08	+0.06	-0.22	-0.10	-0.25	-0.14	-0.25	-0.16	-0.24	-0.16
30°	30°	0.54	0.56	0.35	0.36	0.22	0.22	0.17	0.18	0.14	0.16	0.14	0.16
45°	45°	0.52	0.68	0.42	0.50	0.30	0.34	0.25	0.30	0.20	0.28	0.20	0.26
60°	60°	—	0.82	—	0.62	—	0.44	—	0.36	—	0.30	—	0.28
20°	10°	0.02	0.12	-0.20	-0.6	-0.30	-0.18	-0.29	-0.22	-0.29	-0.24	-0.30	-0.24
30°	10°	0.12	0.08	-0.12	-0.12	-0.26	-0.24	-0.31	-0.26	-0.33	-0.30	-0.32	-0.30

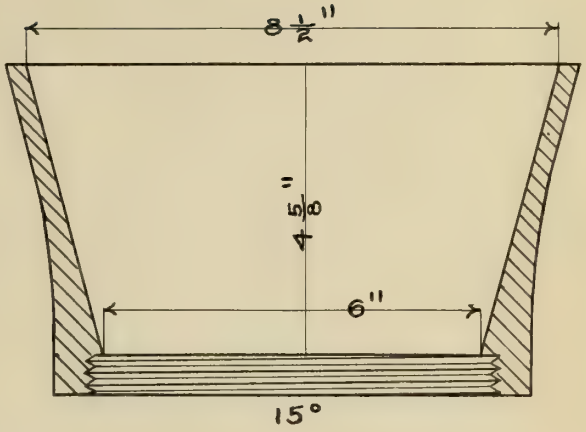
PLATE 1.

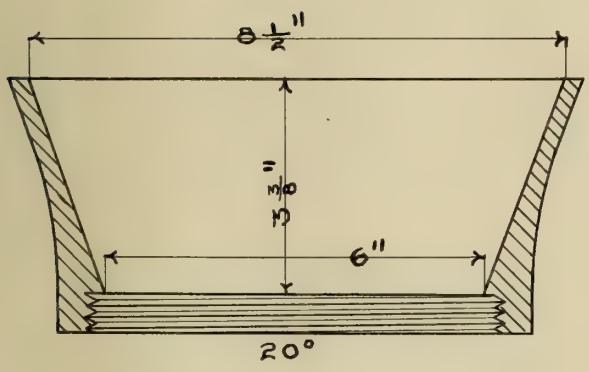


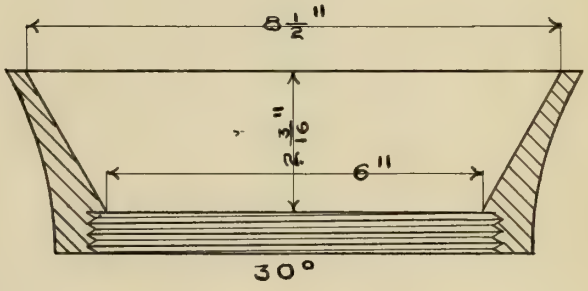
C. C. W. 5-18-04.

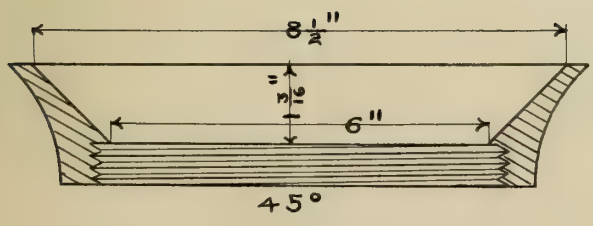
PLATE 2.

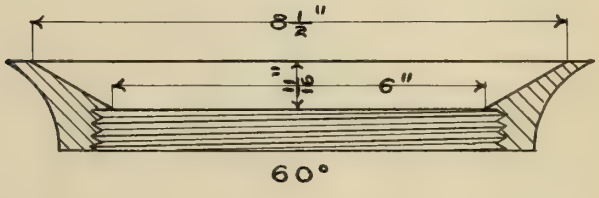








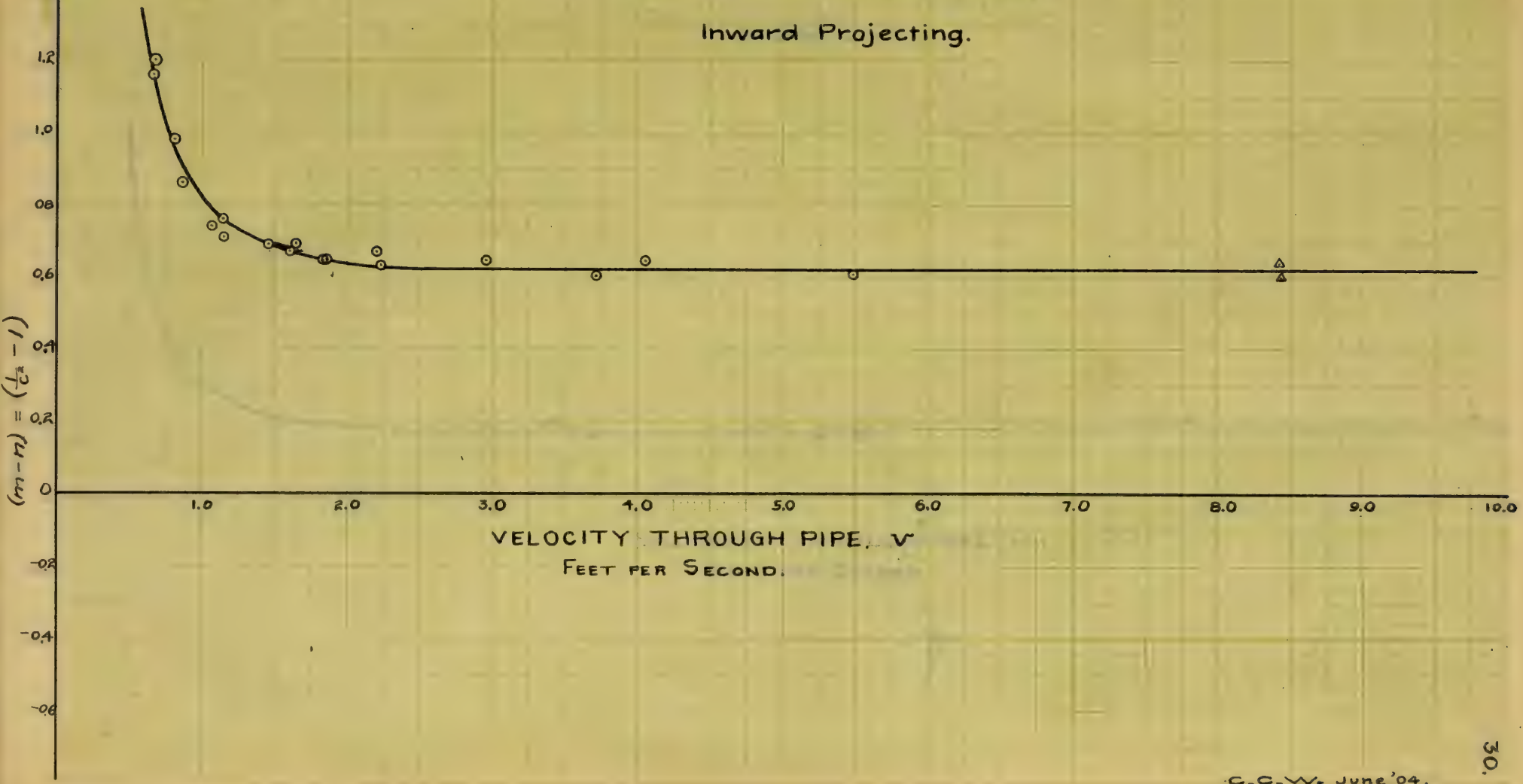




C.C.W. 5-18-04.

PLATE 3.

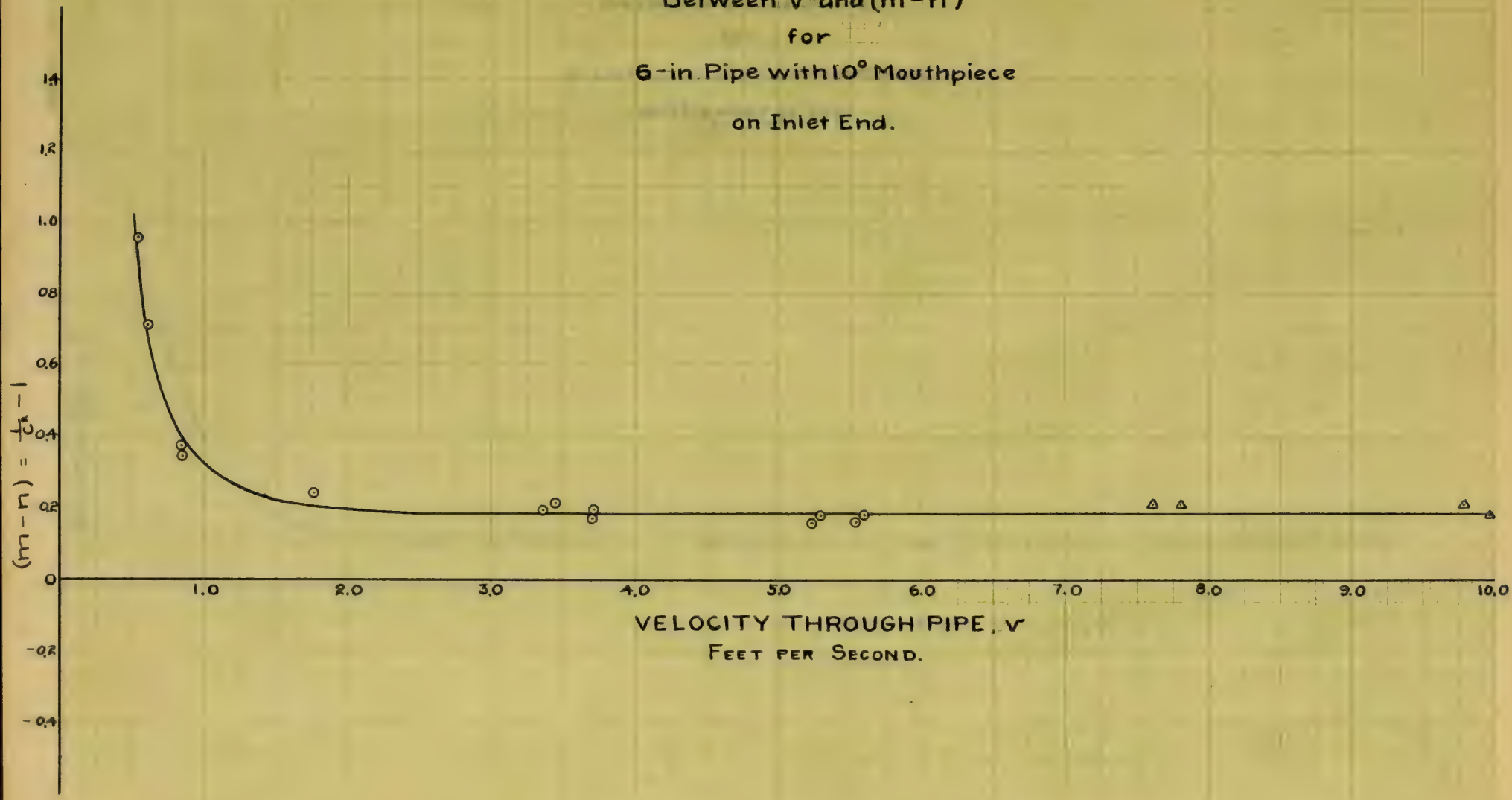
Curve Showing Relation
Between V and (m − n)
for
6-in. Plain Cylindrical Pipe
Inward Projecting.



C.C.W. June '04.

PLATE 4.

Curve Showing Relation
Between v' and $(m-n)$
for
6-in Pipe with 10° Mouthpiece
on Inlet End.



C. C. W. June '04

PLATE 5

Curve Showing Relation
Between v and (m-n)
for
6-in Pipe with 10° Mouthpiece
on Discharge End.

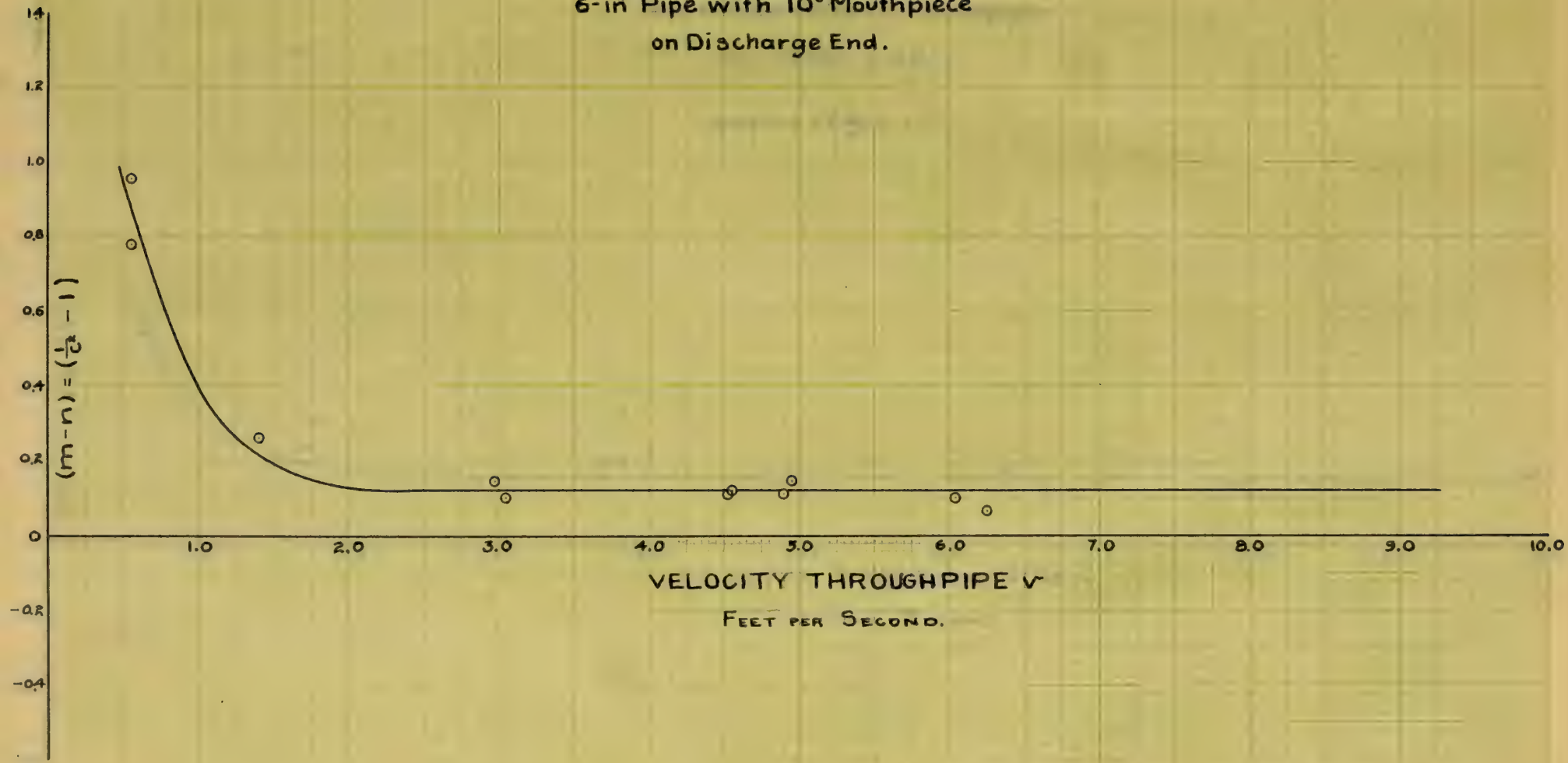
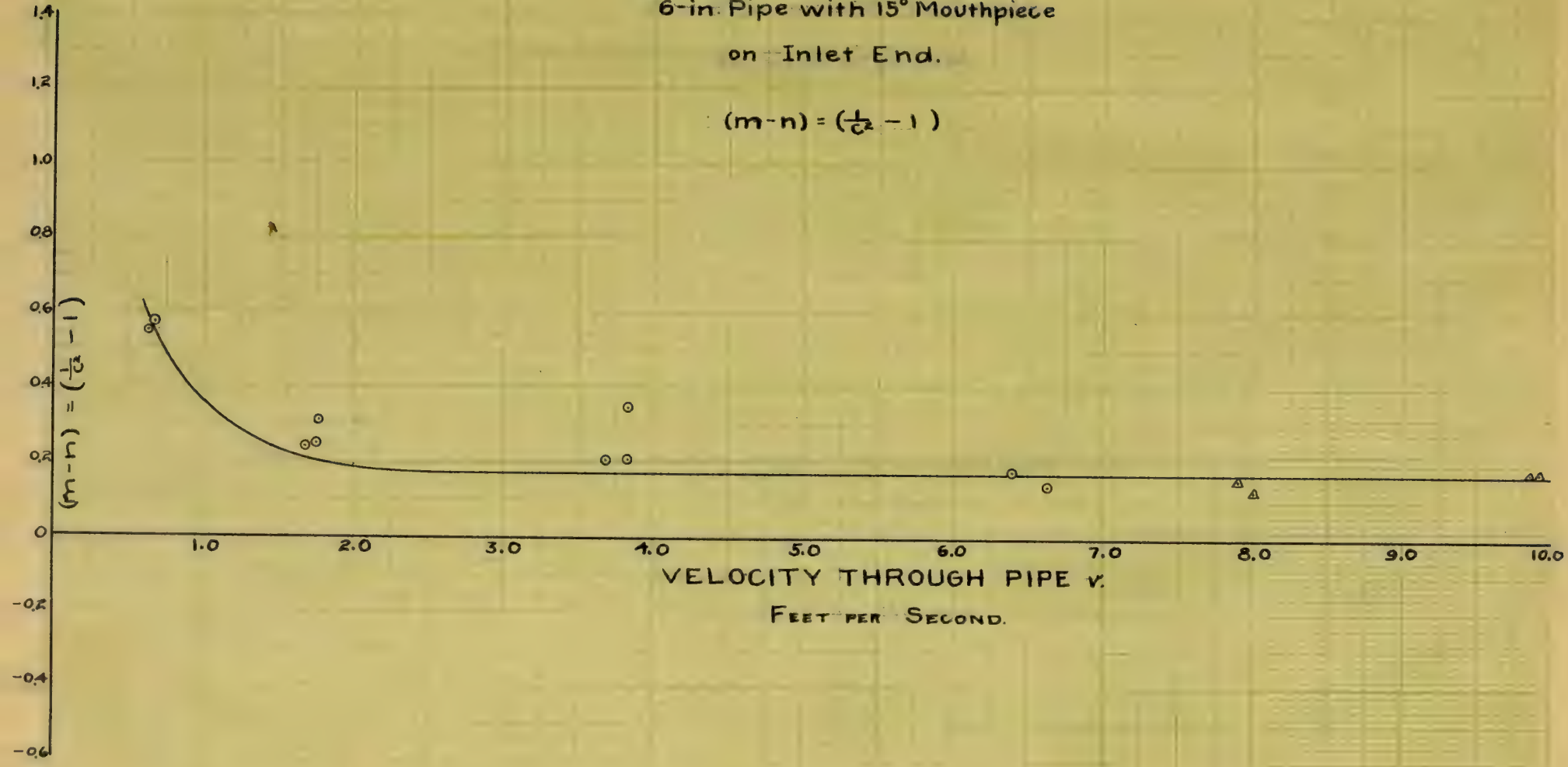


PLATE 6

Curve Showing Relation
Between v and (m-n)
for
6-in. Pipe with 15° Mouthpiece
on Inlet End.

$(m-n) = \left(\frac{1}{C^2} - 1\right)$



C. C. W. June '04.

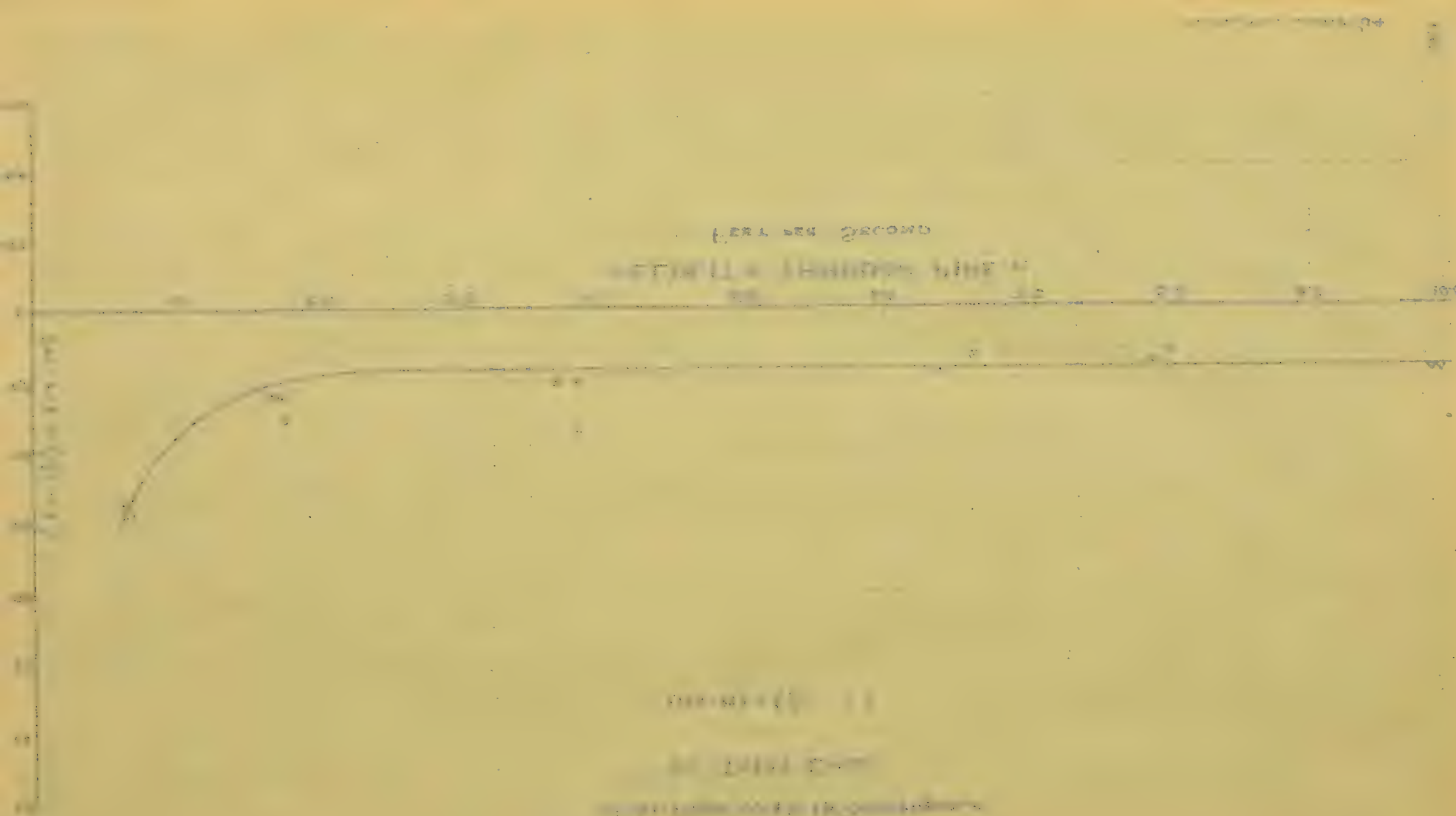
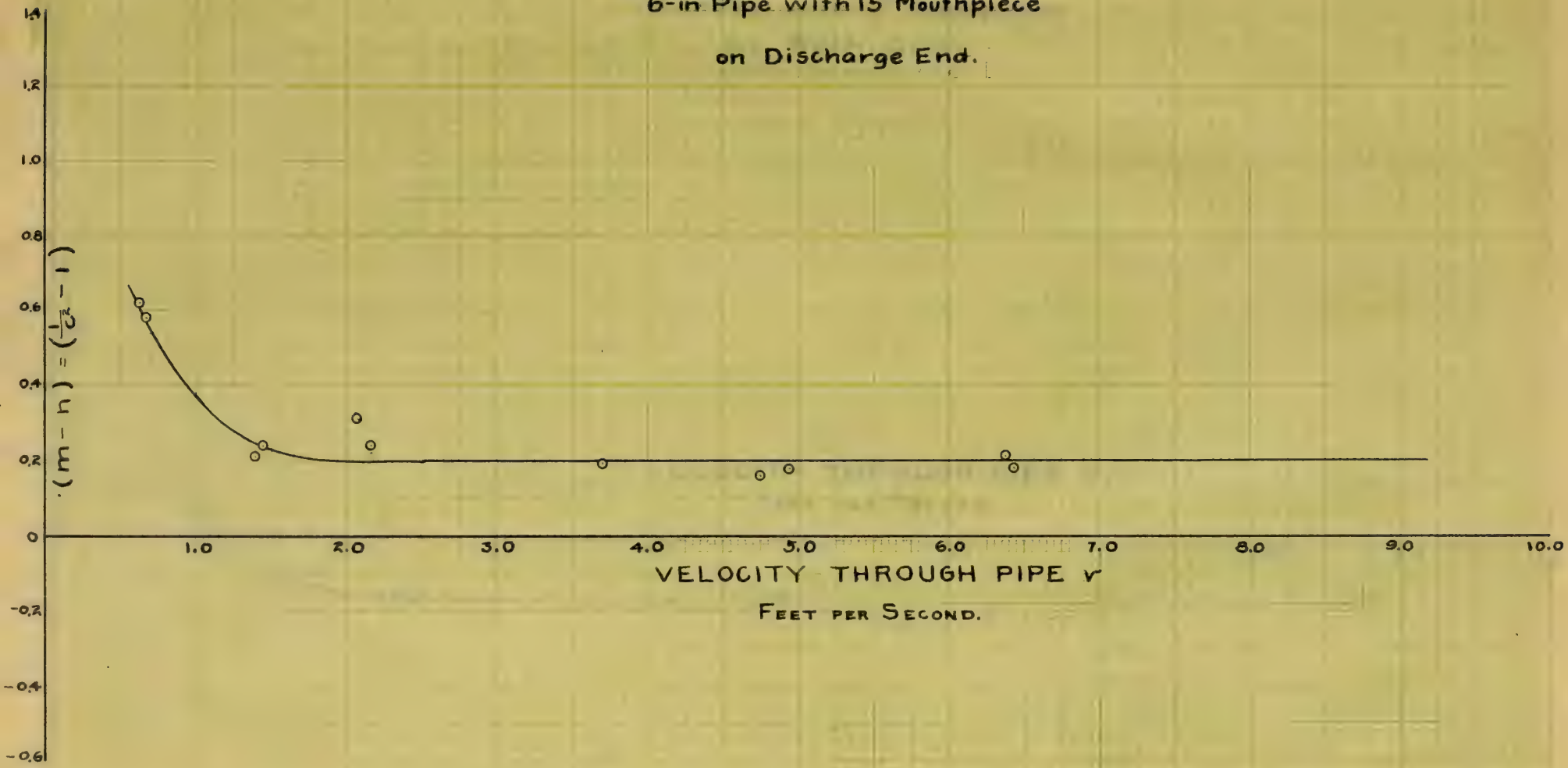


PLATE 7

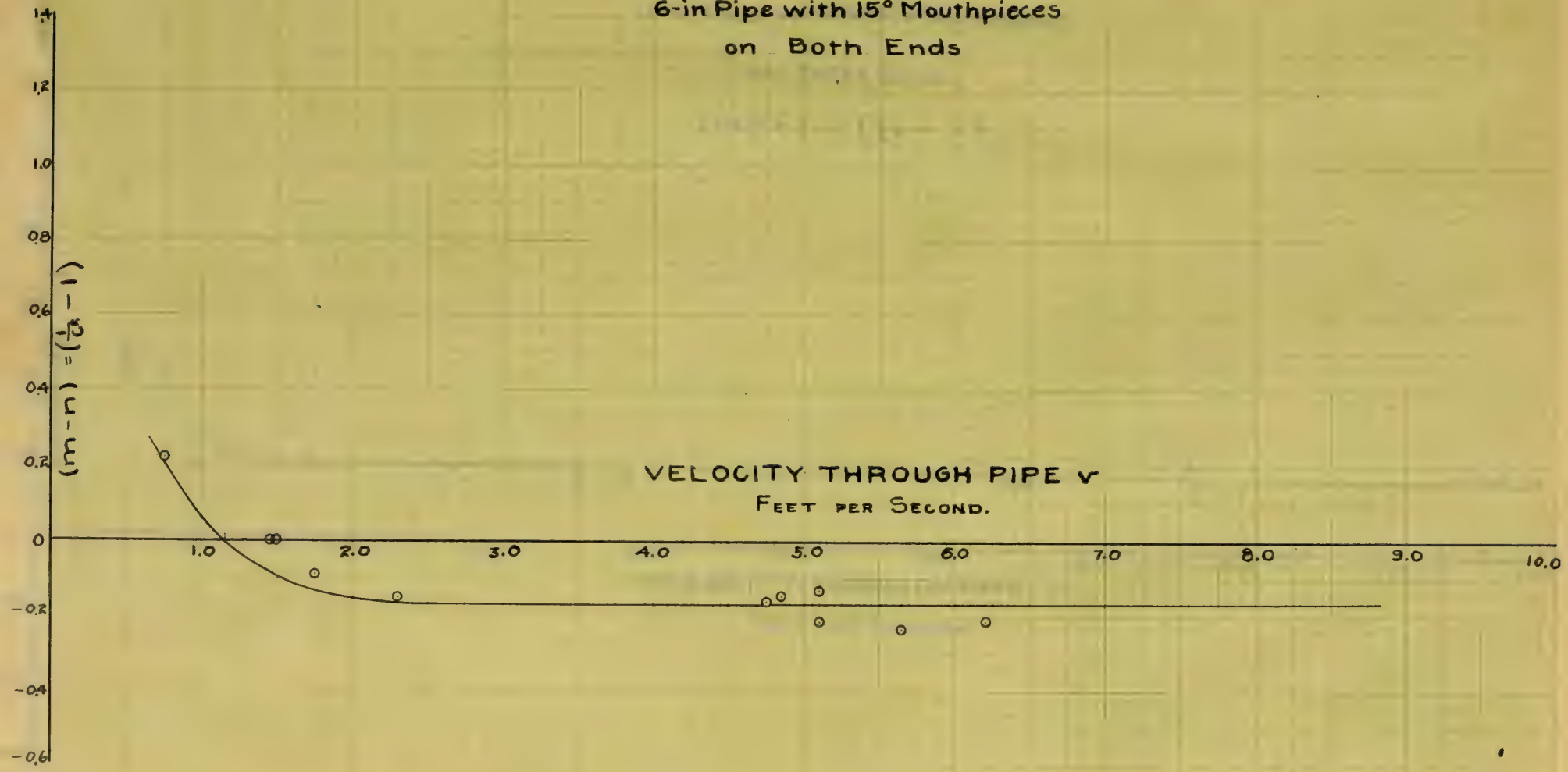
Curve Showing Relation
Between v and (m-n)
for
6-in Pipe with 15° Mouthpiece
on Discharge End.



C. C. W. June '04.

PLATE 8.

Curve Showing Relation
Between v' and (m-n)
for
6-in Pipe with 15° Mouthpieces
on Both Ends



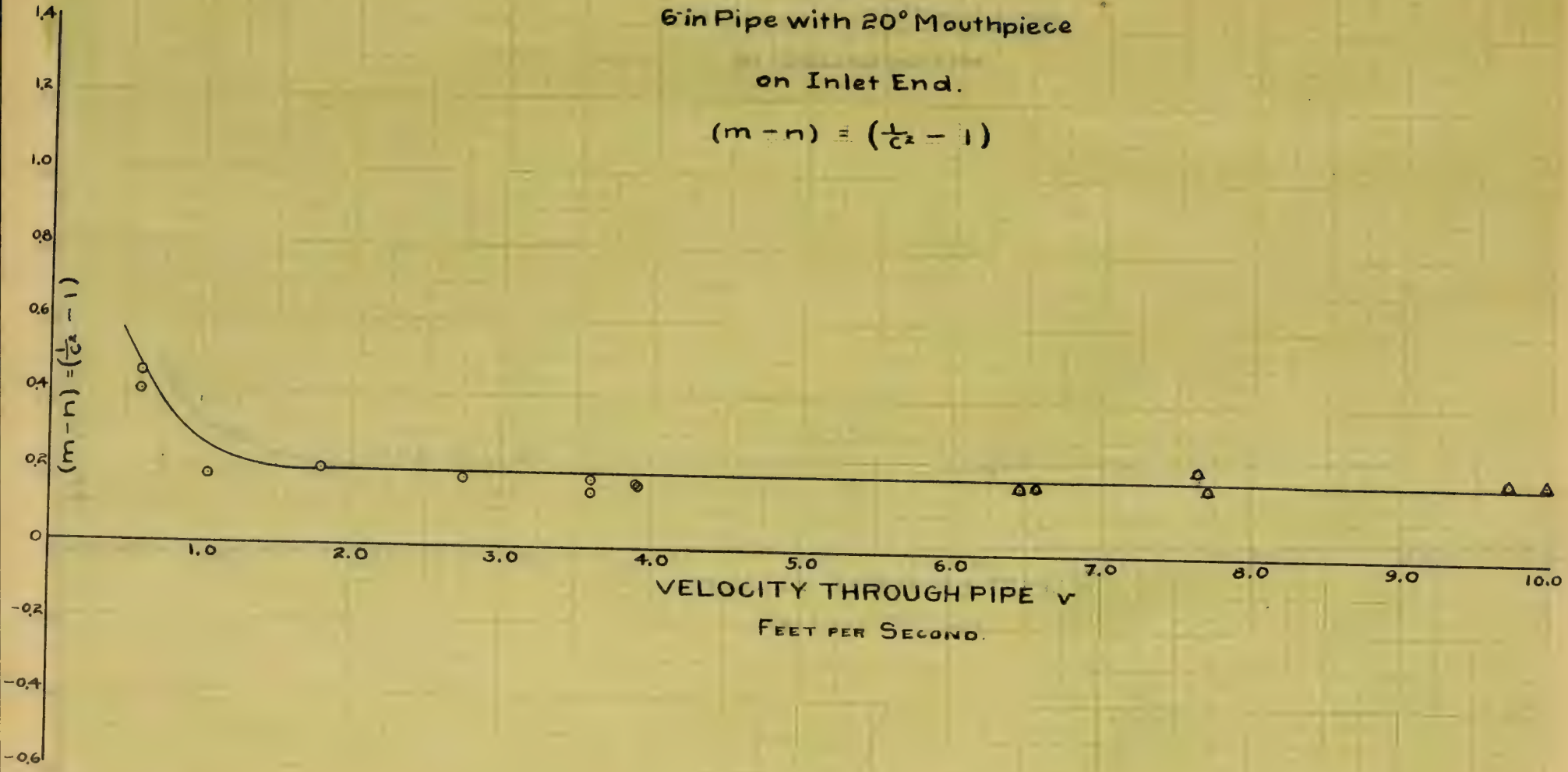
C.C.W. June '04.

VELOCITY THROUGH PIPE V

PLATE 9.

Curve Showing Relation
Between v and (m-n)
for
6 in Pipe with 20° Mouthpiece
on Inlet End.

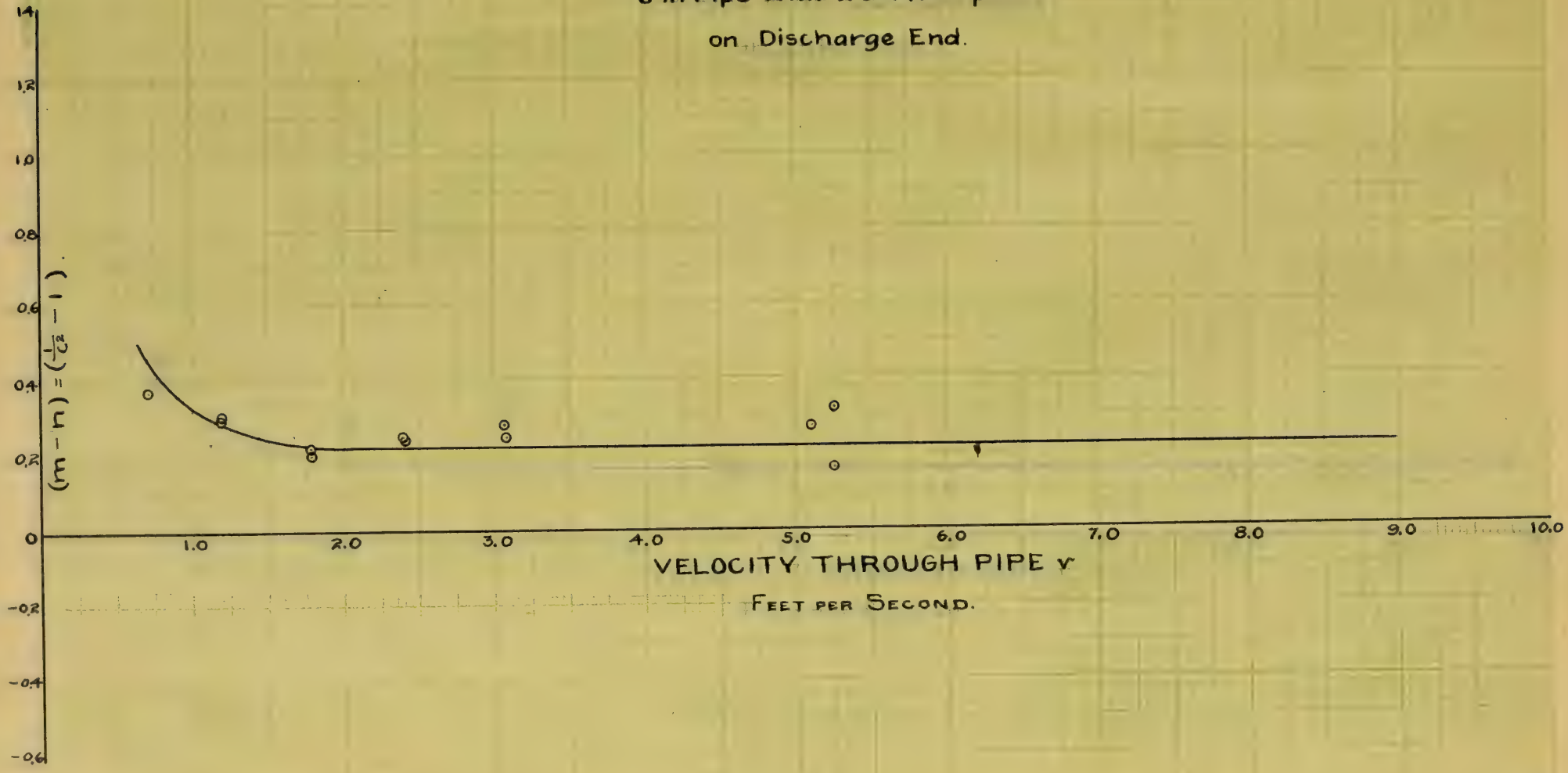
$(m-n) = \left(\frac{1}{C^2} - 1\right)$



C. C. W. June 1904.

PLATE 10

Curve Showing Relation
Between v and $(m-n)$
for
6-in Pipe with 20° Mouthpiece
on Discharge End.

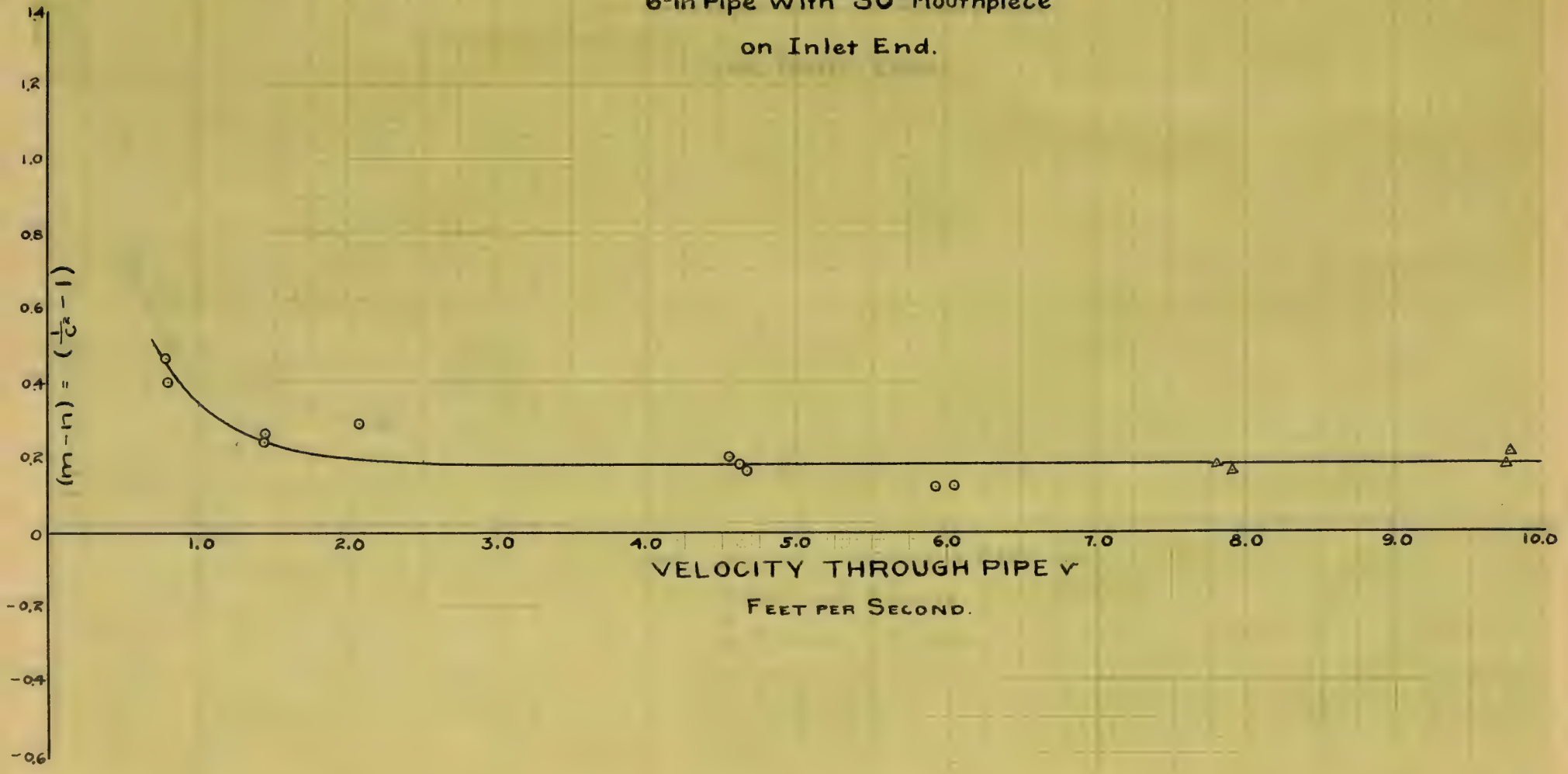


C. C. W. June '04.

PLATE 10

PLATE II

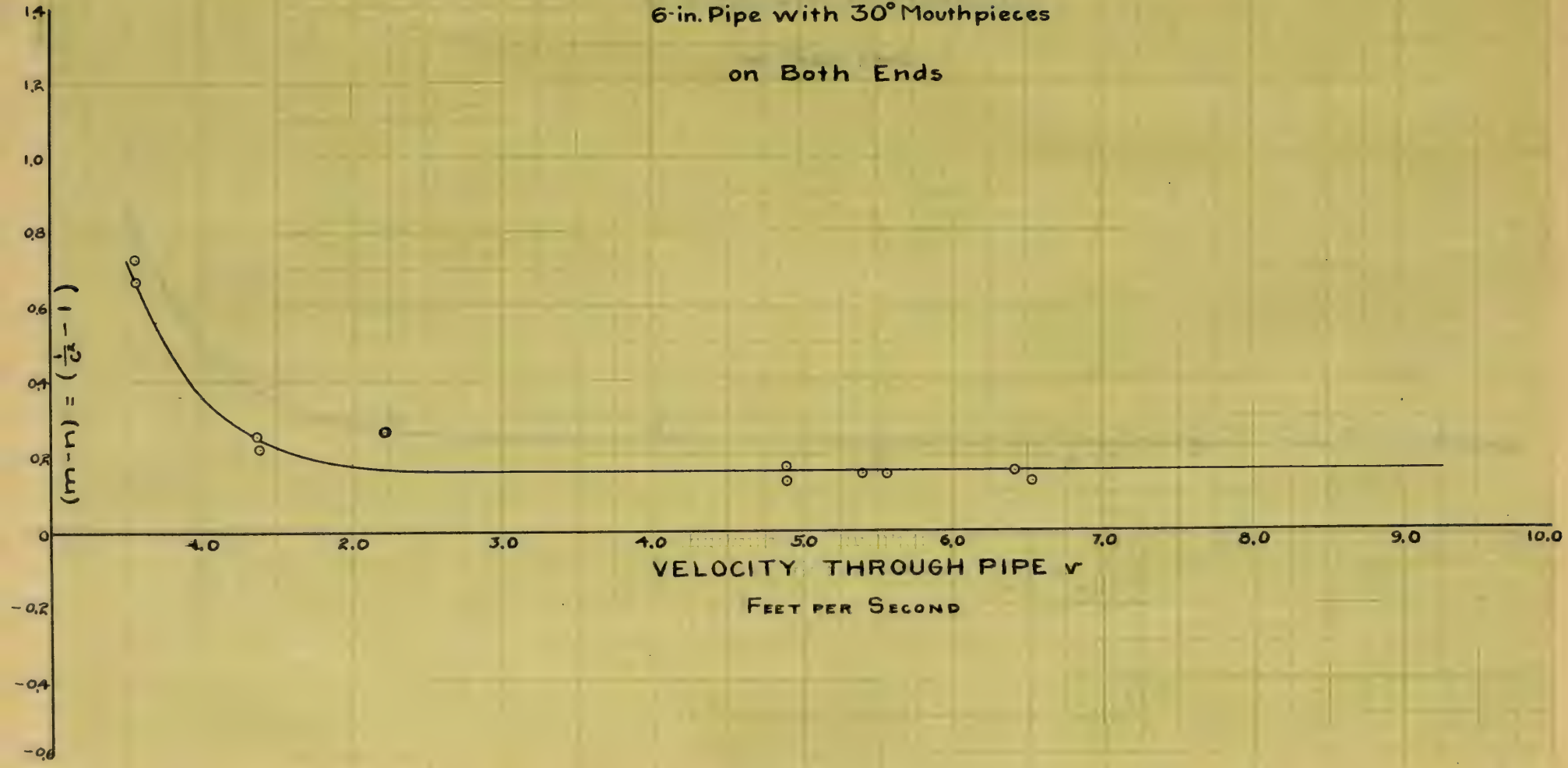
Curve Showing Relation
Between v and $(m-n)$
for
6-in Pipe with 30° Mouthpiece
on Inlet End.



C. C. W. June '04

PLATE 12.

Curve Showing Relation
Between v and (m-n)
for
6-in. Pipe with 30° Mouthpieces
on Both Ends

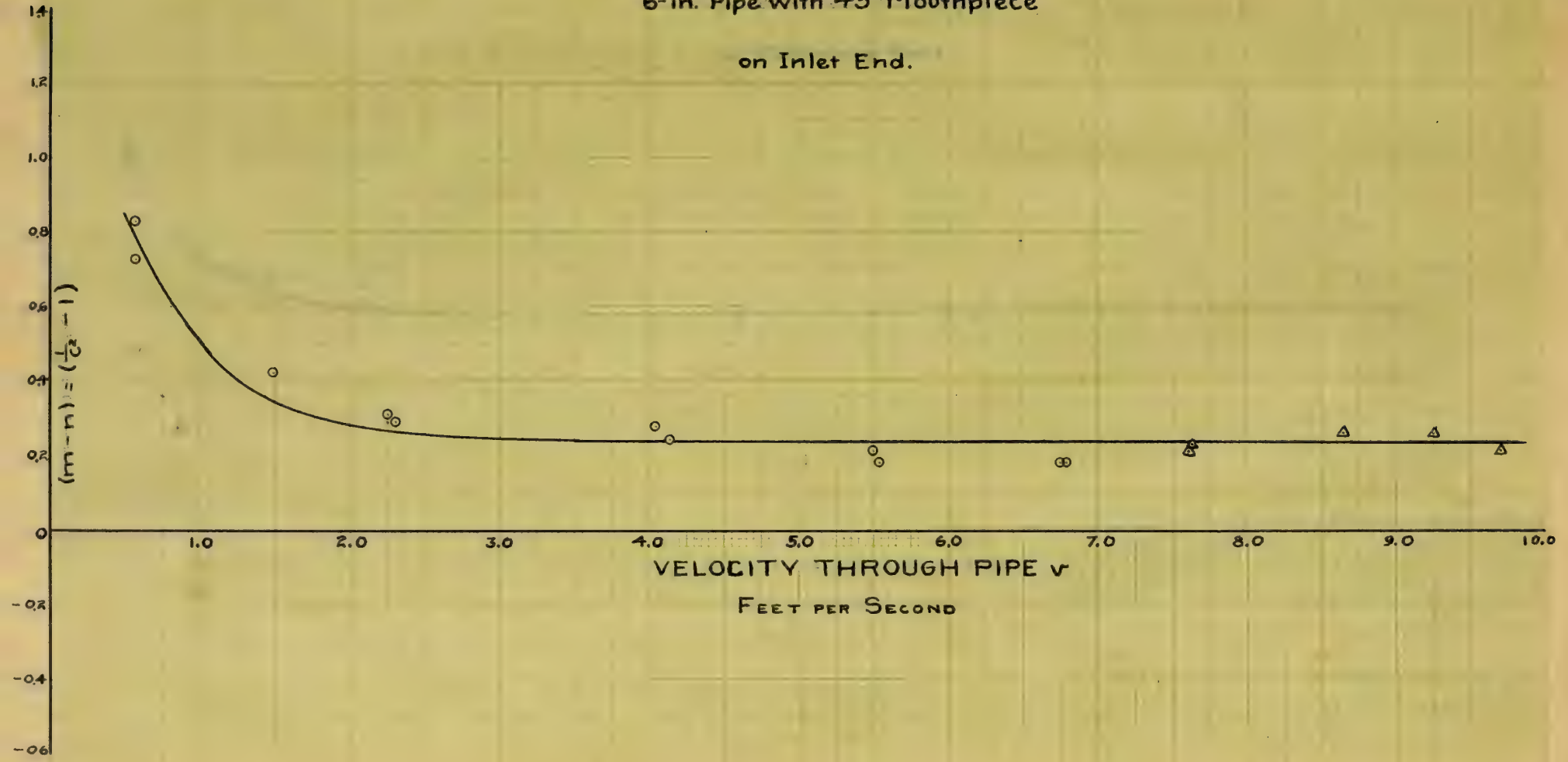


C. C. W. June 1904.

FEET PER SECOND
VELOCITY THROUGH PIPE V

PLATE 13

Curve Showing Relation
Between v and $(m-n)$
for
6-in. Pipe with 45° Mouthpiece
on Inlet End.



C. C. W. June '04.

PLATE 14

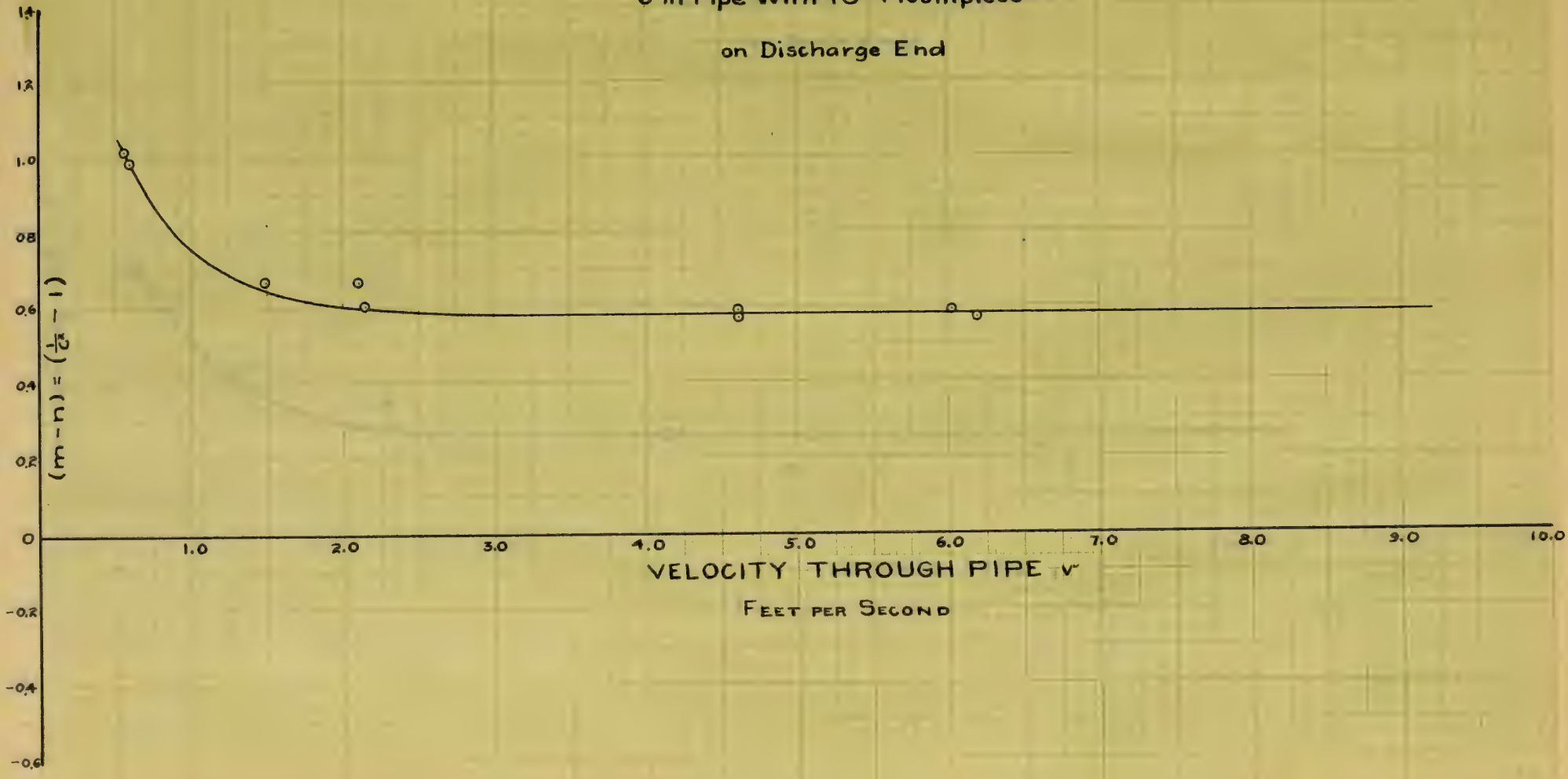
Curve Showing Relation

Between v and (m-n)

for

6-in Pipe with 45° Mouthpiece

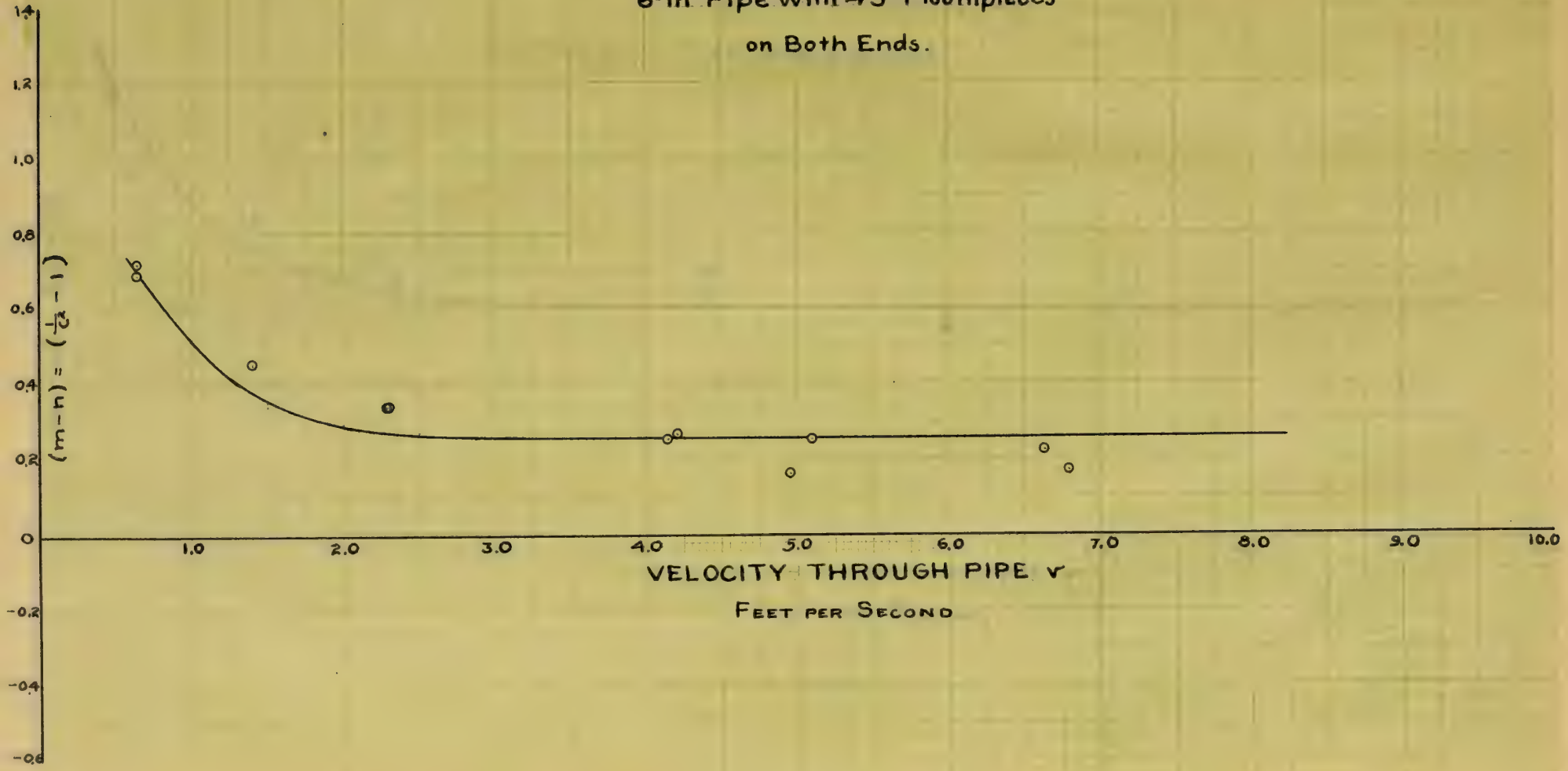
on Discharge End



C. C. W. June '04

PLATE 15.

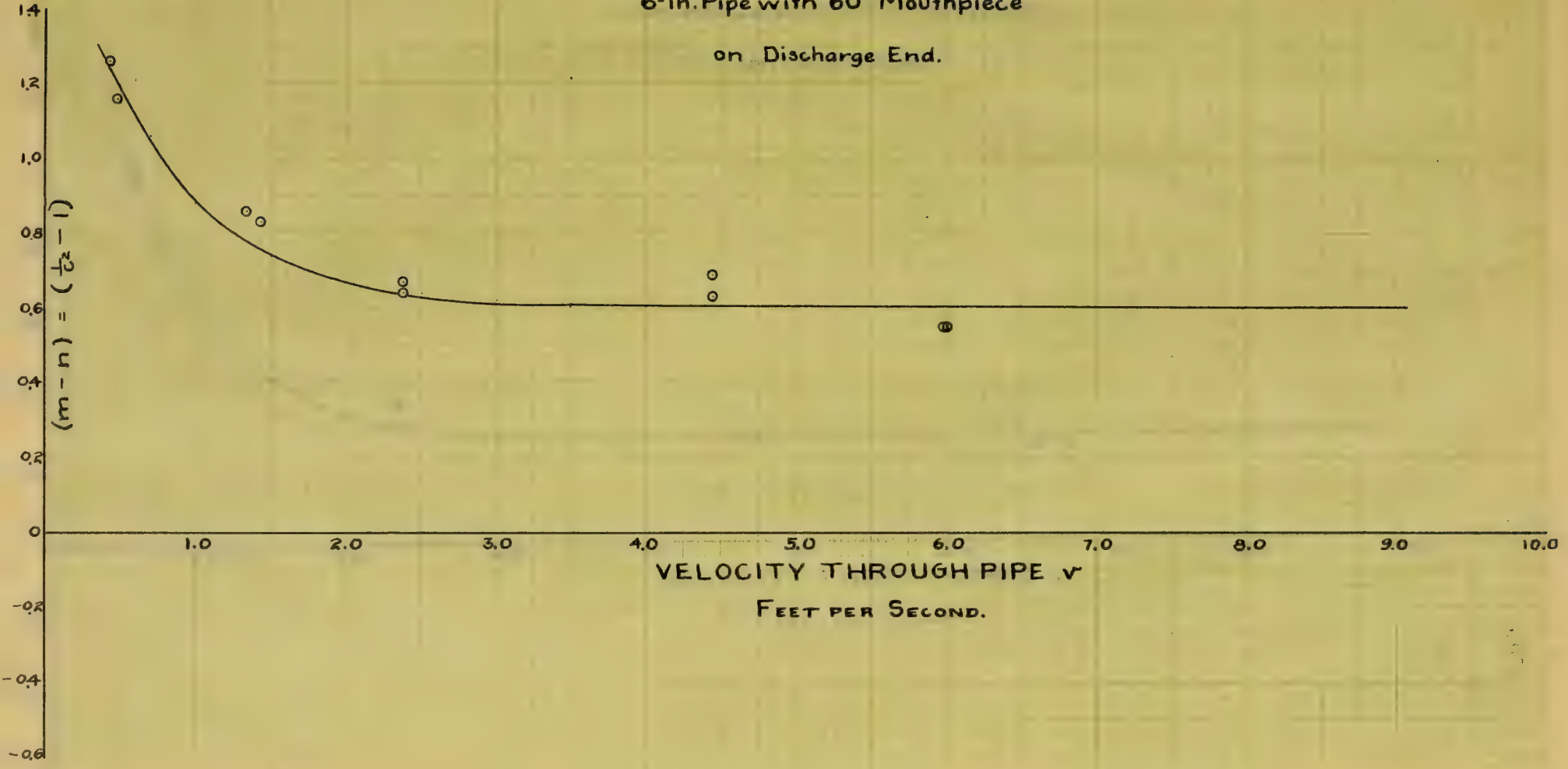
Curve Showing Relation
Between r and (m-n)
for
6-in Pipe with 45° Mouthpieces
on Both Ends.



C. C. W. June '04

PLATE 16.

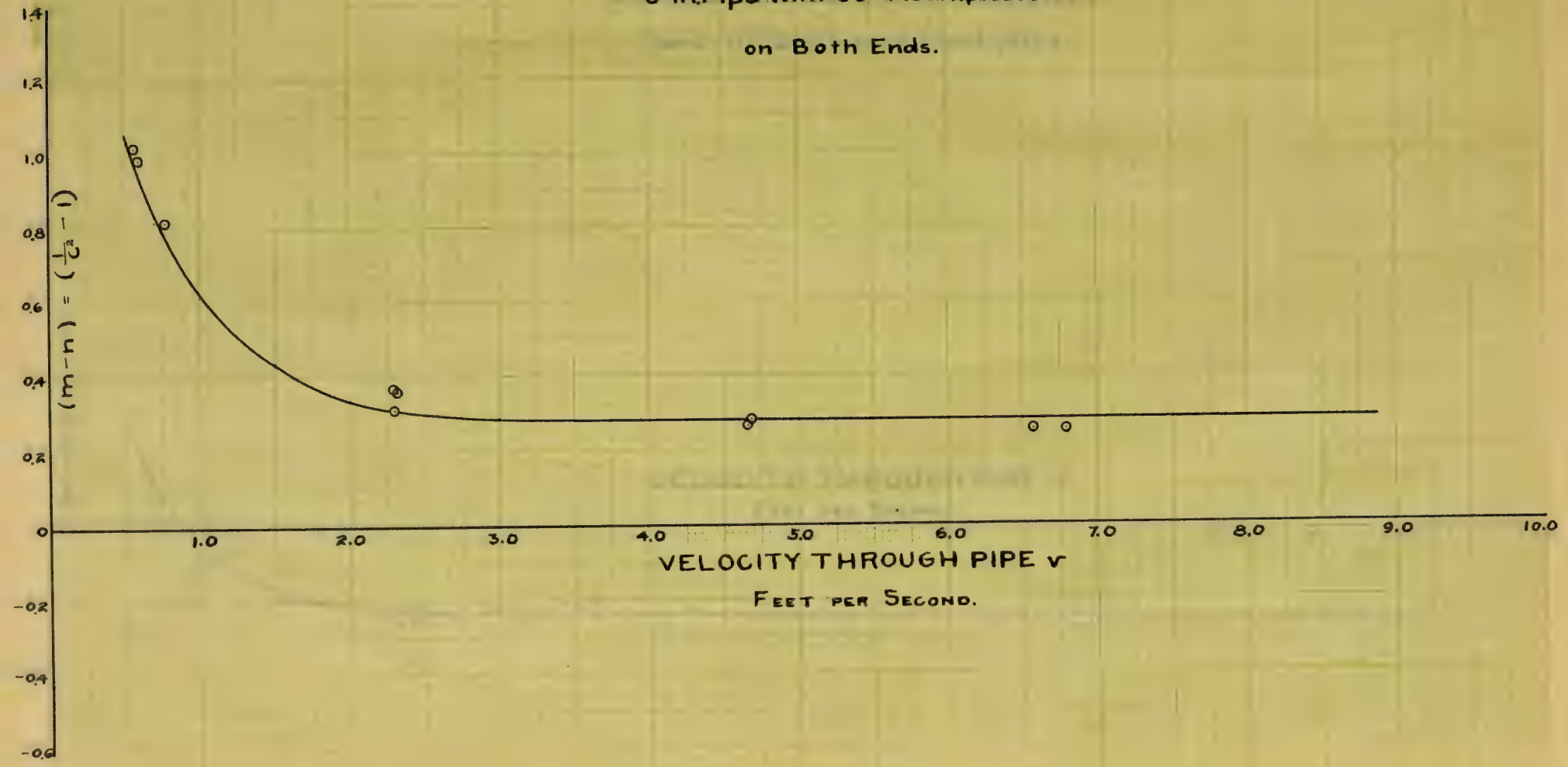
Curve Showing Relation
Between v and (m - n)
for
6-in. Pipe with 60° Mouthpiece
on Discharge End.



C. C. W. June '04.

PLATE 17.

Curve Showing Relation
Between v and (m-n)
for
6-in. Pipe with 60° Mouthpieces
on Both Ends.



C. C. W. June '04.

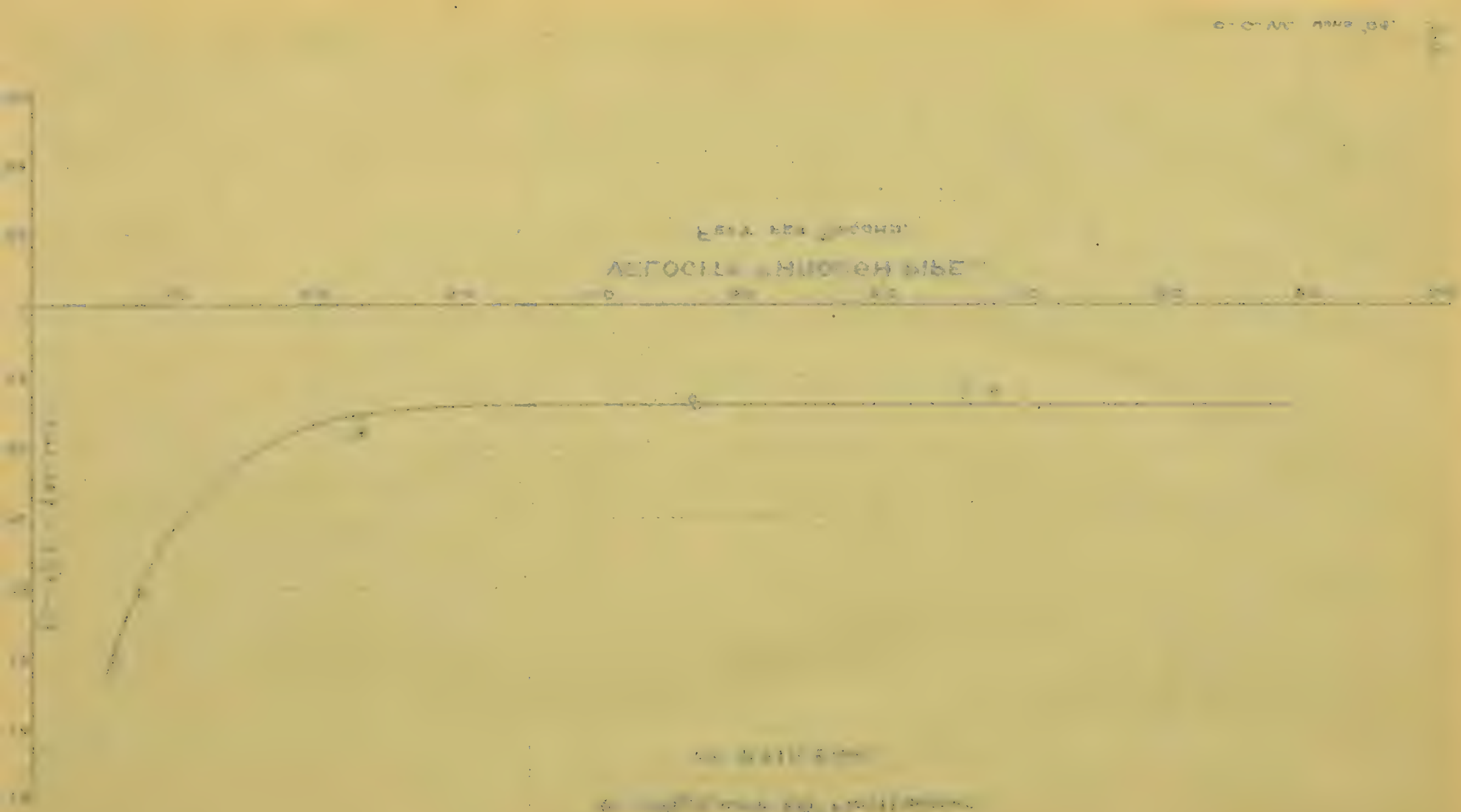
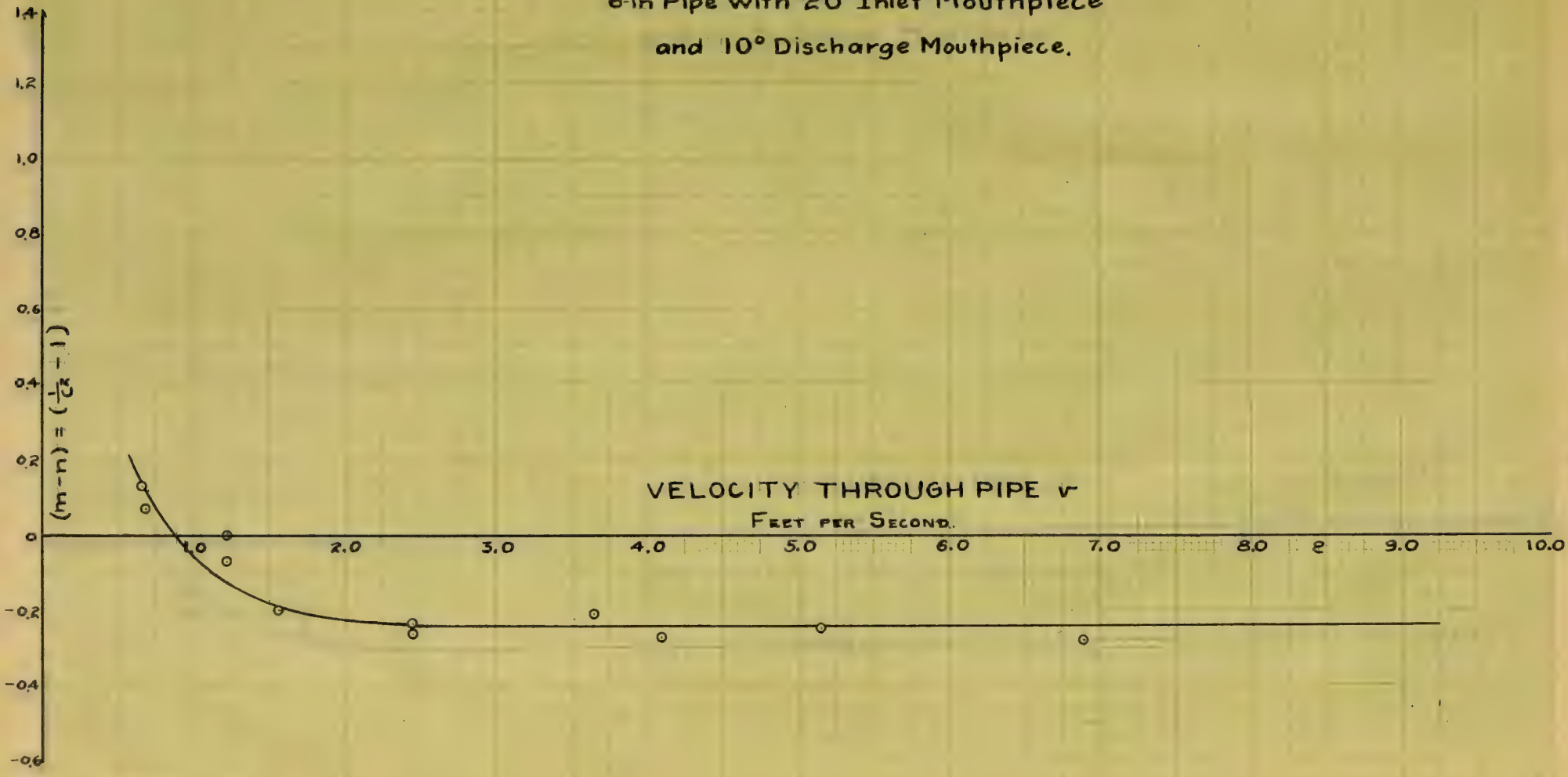


PLATE 18.

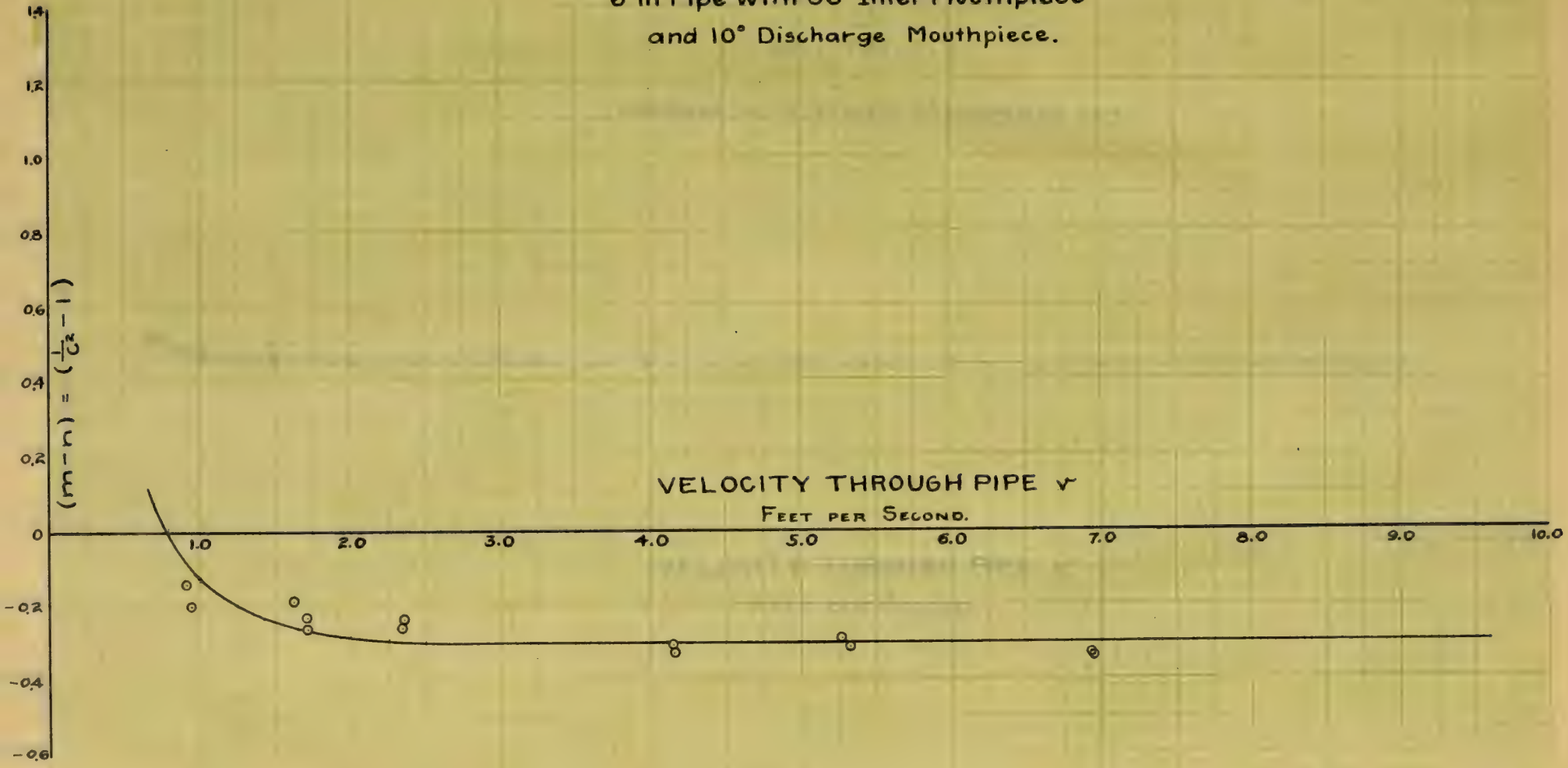
Curve Showing Relation
Between v and (m-n)
for
6-in Pipe with 20° Inlet Mouthpiece
and 10° Discharge Mouthpiece.



C. C. W. June '04.

PLATE 19.

Curve Showing Relation
Between v and (m-n)
for
6-in Pipe with 30° Inlet Mouthpiece
and 10° Discharge Mouthpiece.



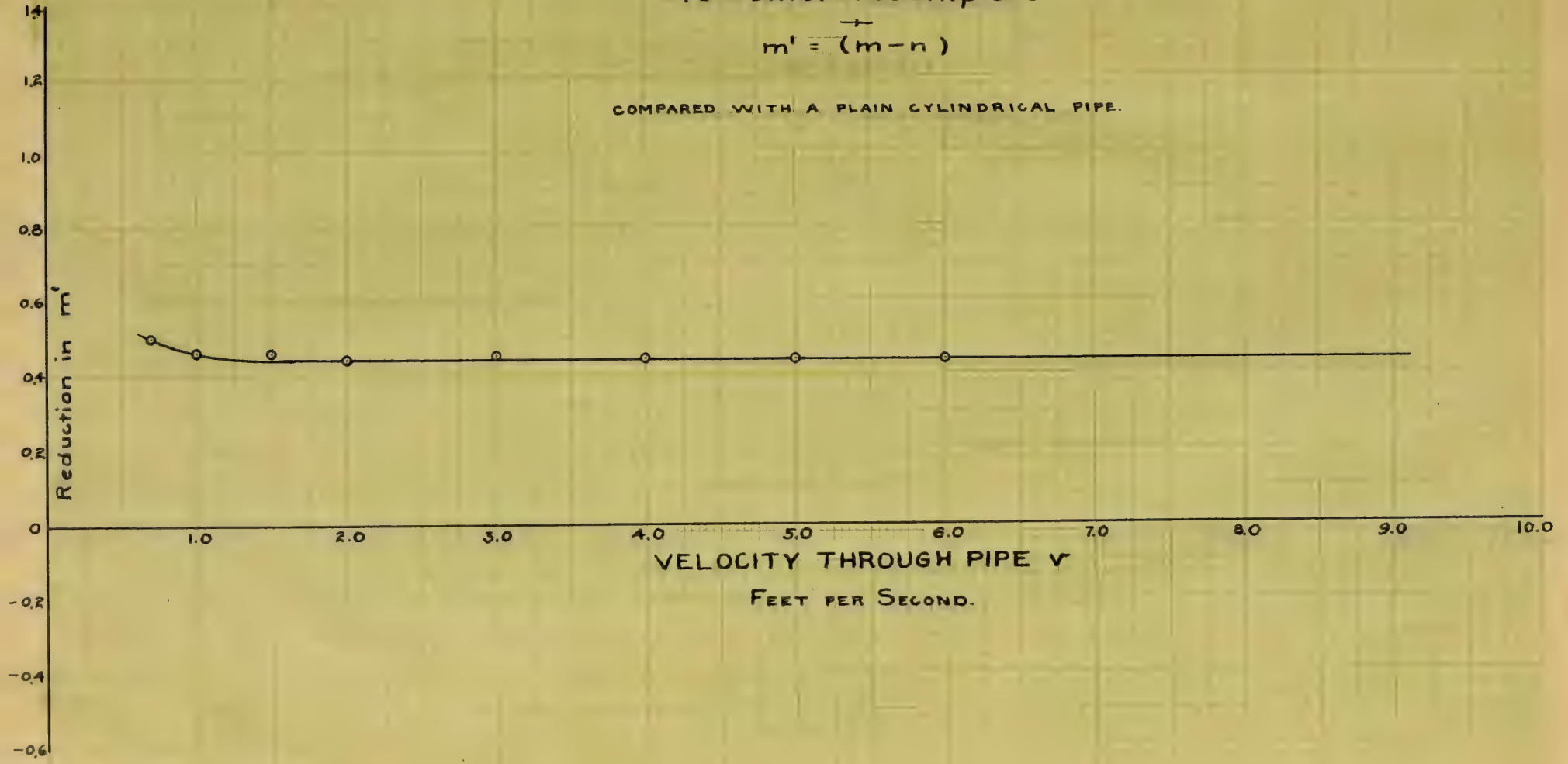
C.C.W. June 1904.

PLATE 20

Curve Showing Reduction
in m' for a 6-in Pipe
Due to a
10° Inlet Mouthpiece

$$m' = \frac{}{+}(m-n)$$

COMPARED WITH A PLAIN CYLINDRICAL PIPE.



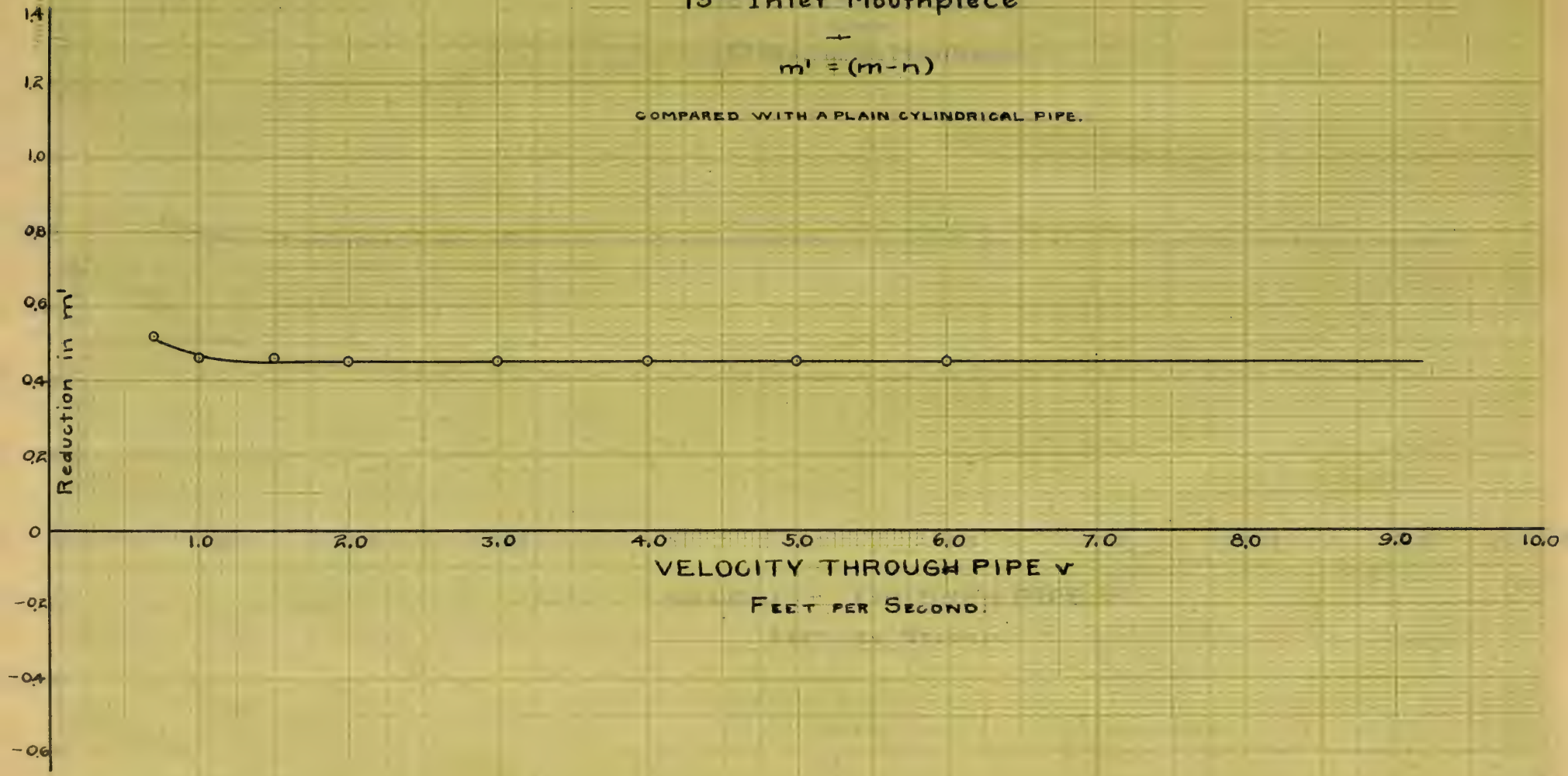
C.C.W. June '04.

PLATE 21

Curve Showing Reduction
in m' for a 6-in. Pipe
Due to a
15° Inlet Mouthpiece

$$m' = (m - n)$$

COMPARED WITH A PLAIN CYLINDRICAL PIPE.

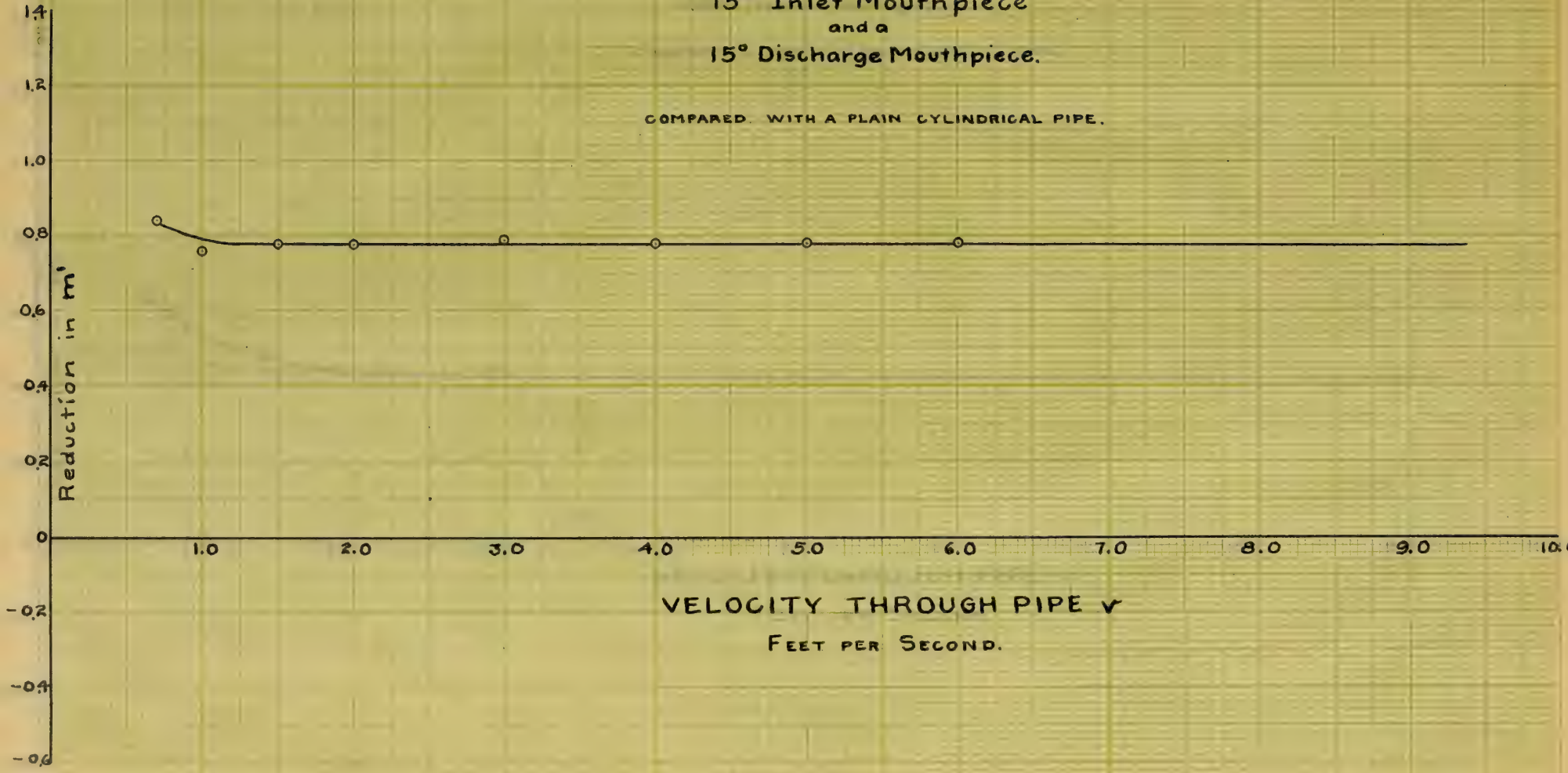


C. C. W. June '04.

PLATE 22.

Curve Showing Reduction
in m' for 6 in. Pipe
Due to a
15° Inlet Mouthpiece
and a
15° Discharge Mouthpiece.

COMPARED WITH A PLAIN CYLINDRICAL PIPE.

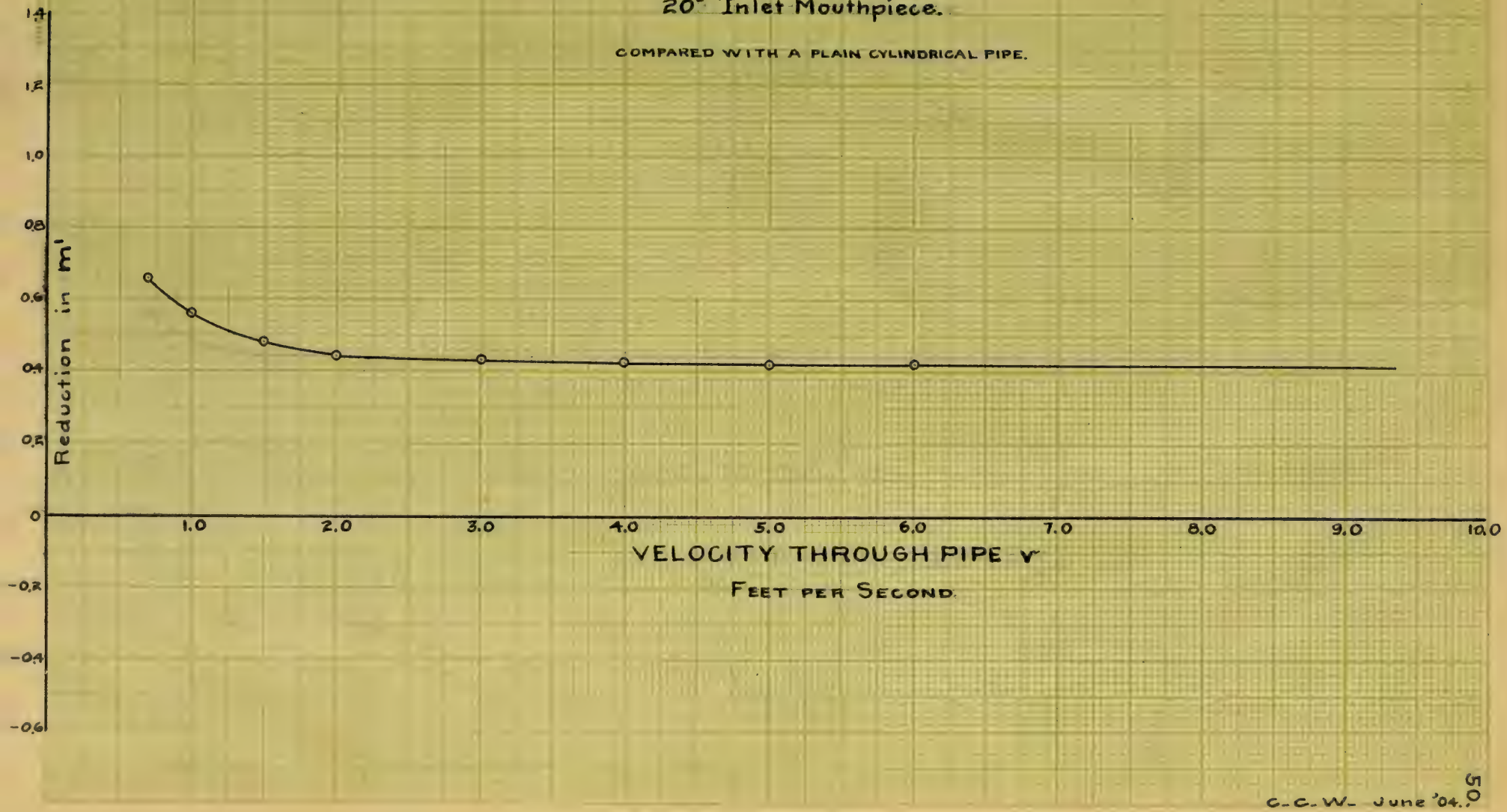


C.C.W. June '04.

PLATE 23.

Curve Showing Reduction
in m' for 6-in Pipe
Due to a.
20° Inlet Mouthpiece.

COMPARED WITH A PLAIN CYLINDRICAL PIPE.

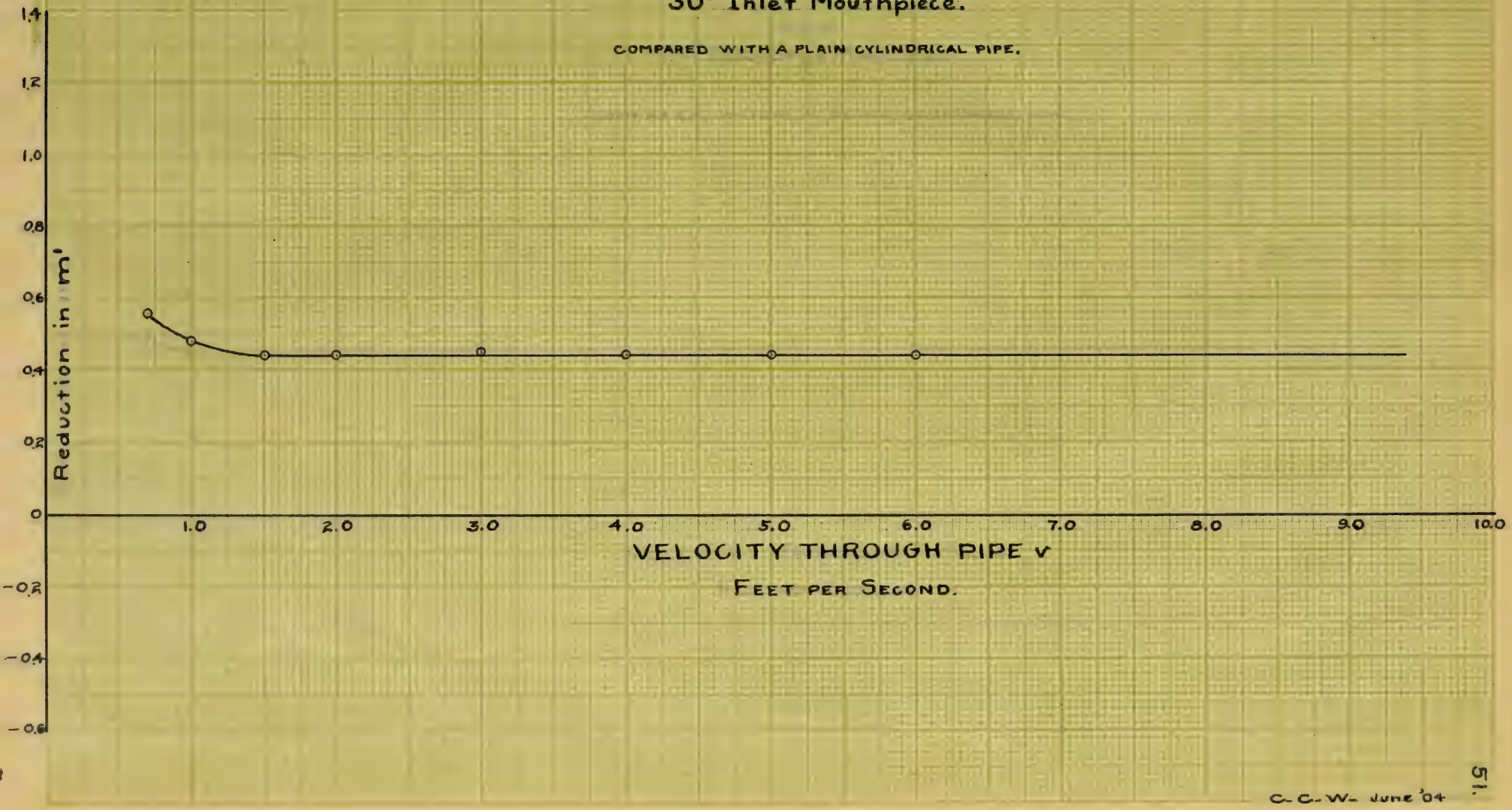


C.C.W. June '04.

PLATE 24.

Curve Showing Reduction
in m' for 6-in. Pipe
Due to a.
30° Inlet Mouthpiece.

COMPARED WITH A PLAIN CYLINDRICAL PIPE.

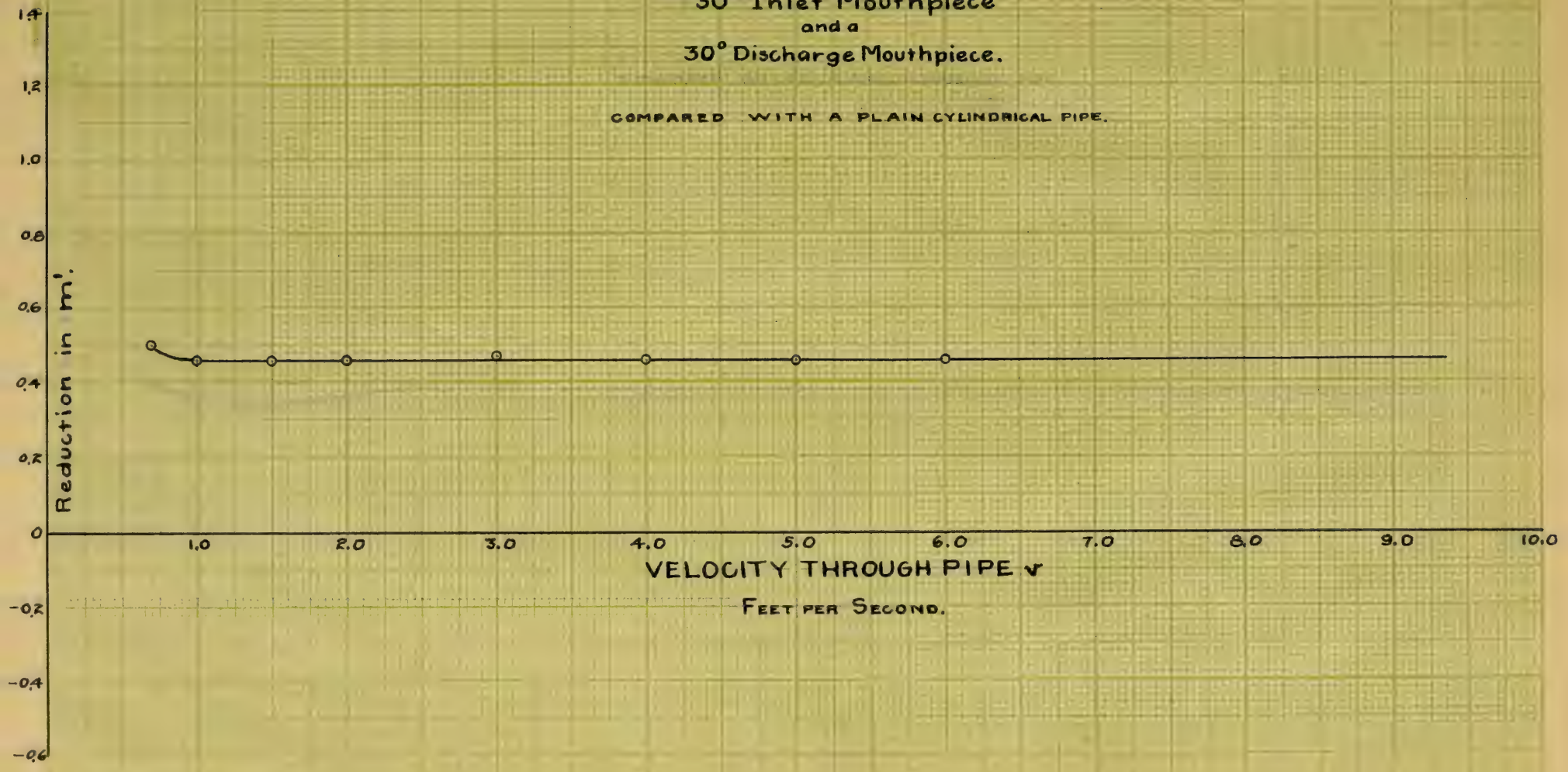


C-C-W- June '04

PLATE 25.

Curve Showing Reduction
in m' for 6-in Pipe
Due to a
30° Inlet Mouthpiece
and a
30° Discharge Mouthpiece.

COMPARED WITH A PLAIN CYLINDRICAL PIPE.

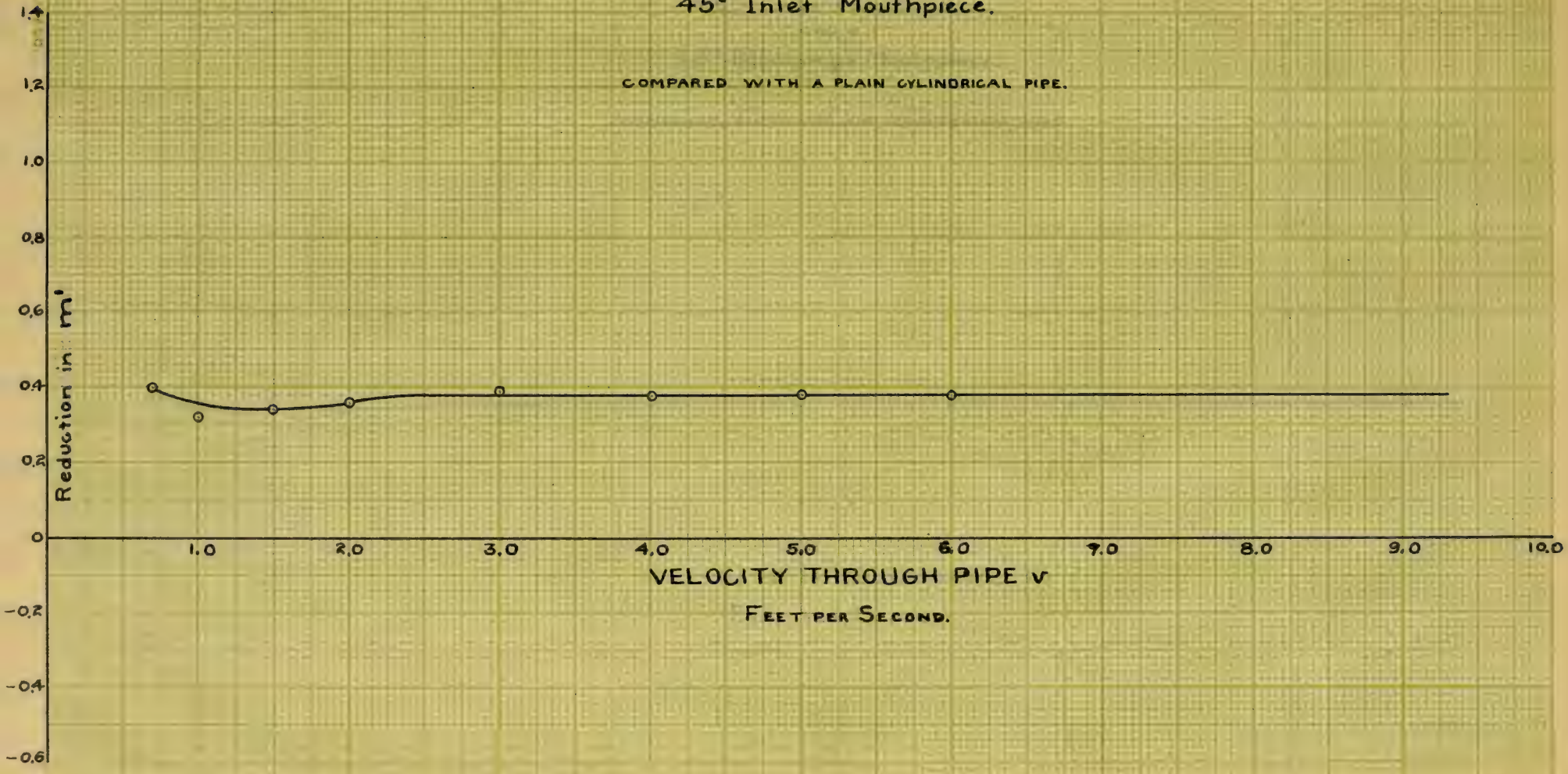


C-C-W. June '04

PLATE 26.

Curve Showing Reduction
in m' for 6-in. Pipe
Due to a
45° Inlet Mouthpiece.

COMPARED WITH A PLAIN CYLINDRICAL PIPE.



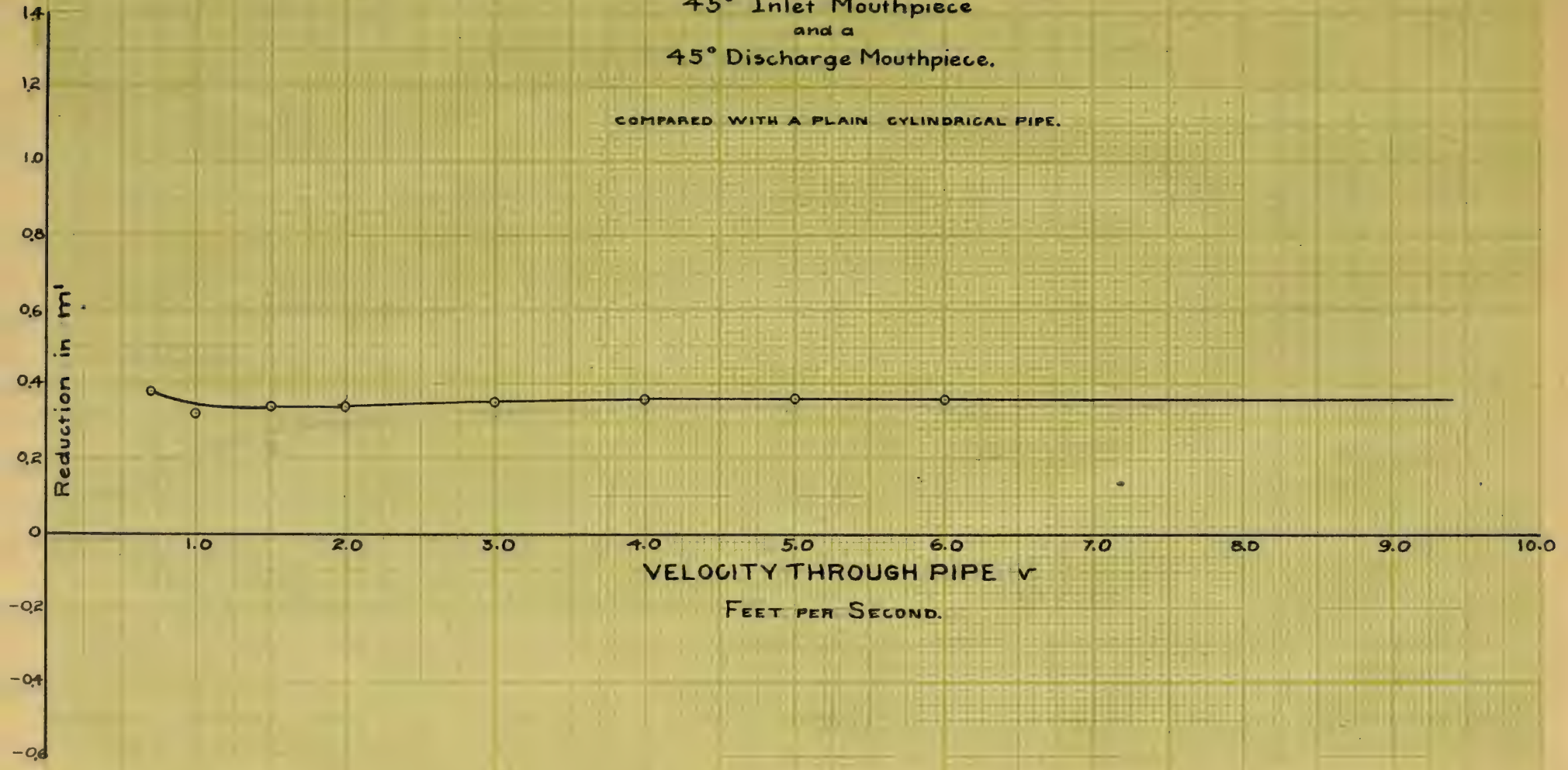
C.C.W. June 1904.

53.

PLATE 27.

Curve Showing Reduction in m' for 6-in. Pipe Due to a 45° Inlet Mouthpiece and a 45° Discharge Mouthpiece.

COMPARED WITH A PLAIN CYLINDRICAL PIPE.

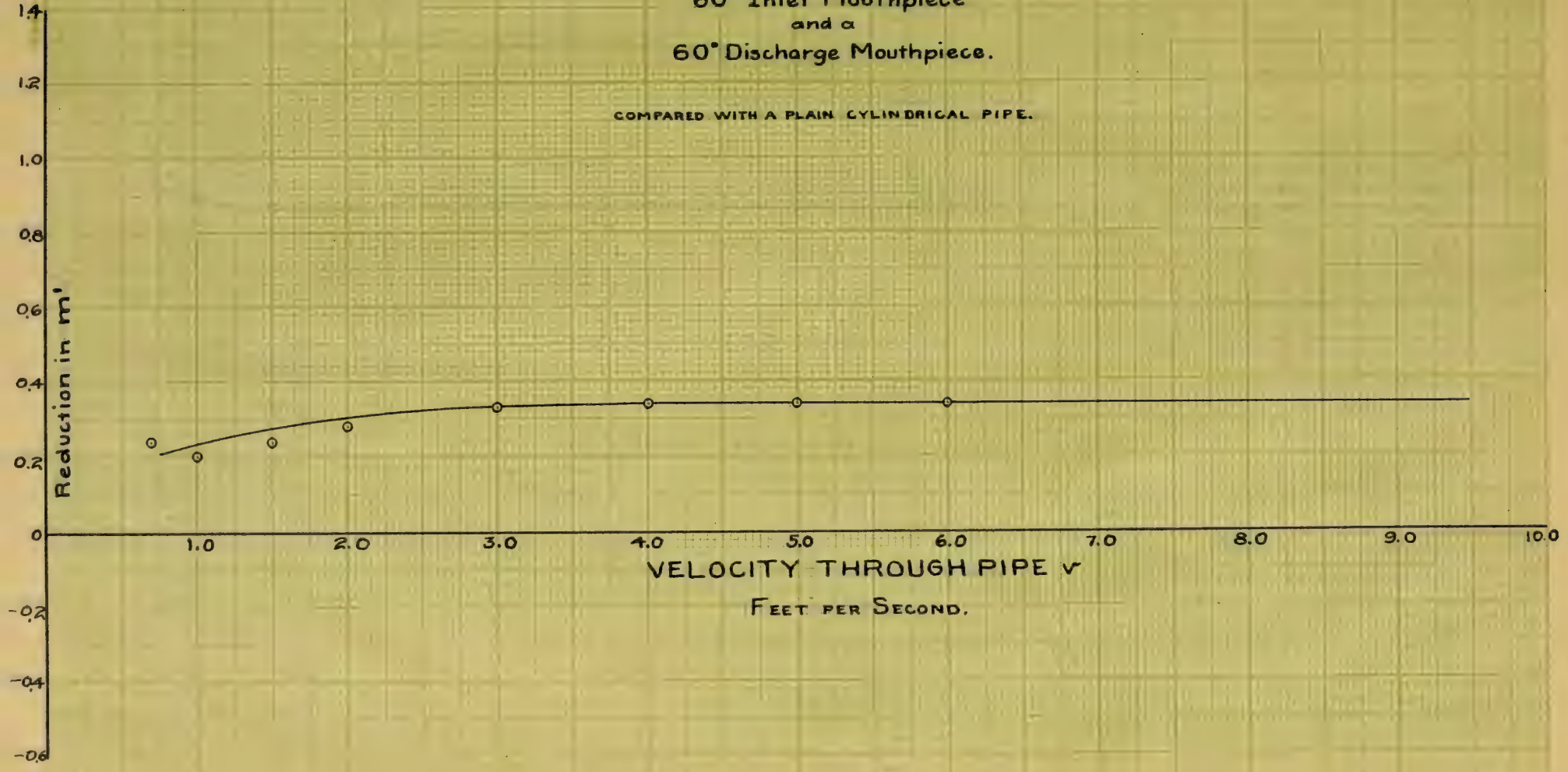


C. C. W. June '04.

PLATE 28.

Curve Showing Reduction
in m' for 6-in Pipe
Due to a
60° Inlet Mouthpiece
and a
60° Discharge Mouthpiece.

COMPARED WITH A PLAIN CYLINDRICAL PIPE.



C. C. W. June 1904.

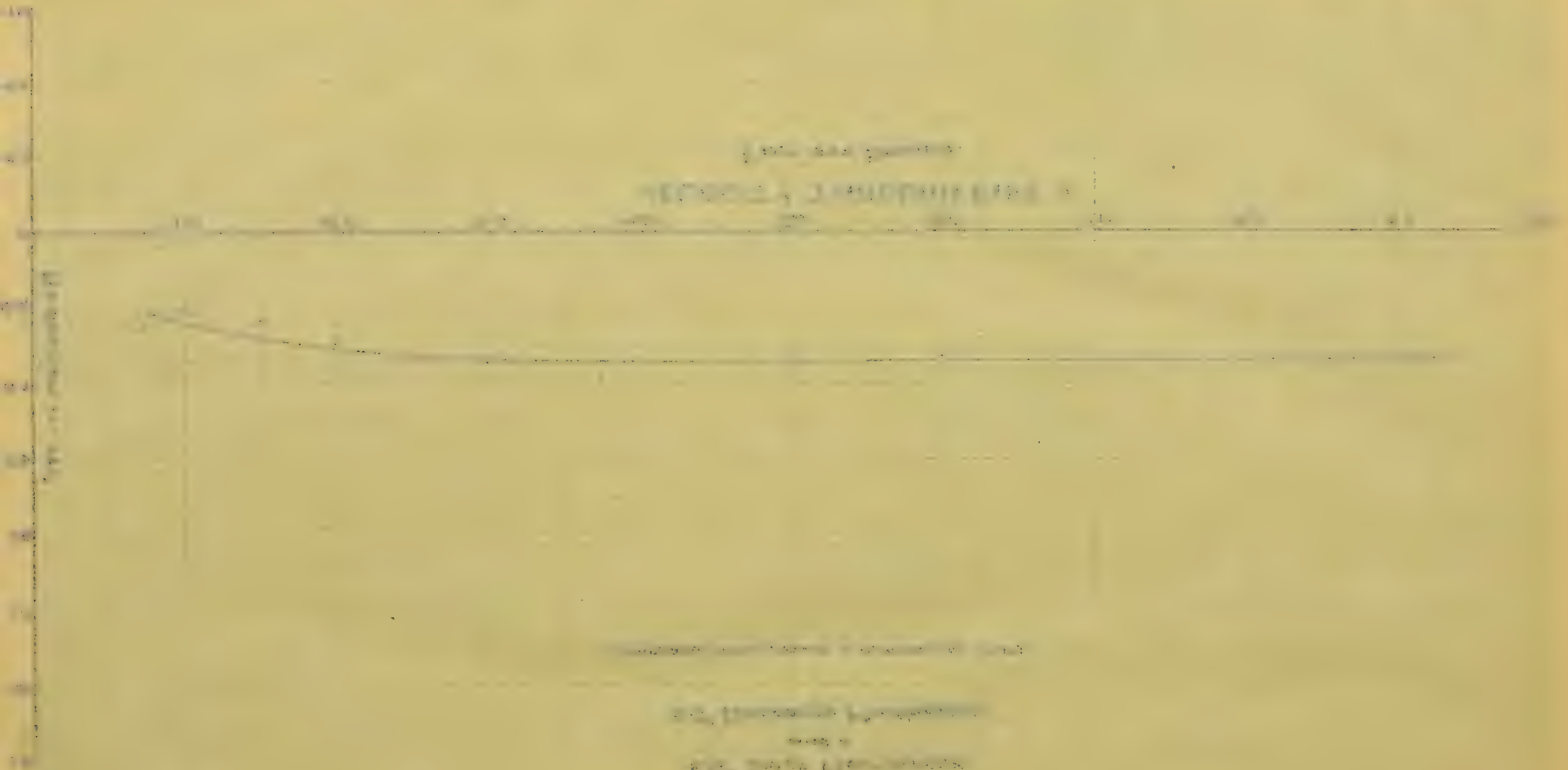
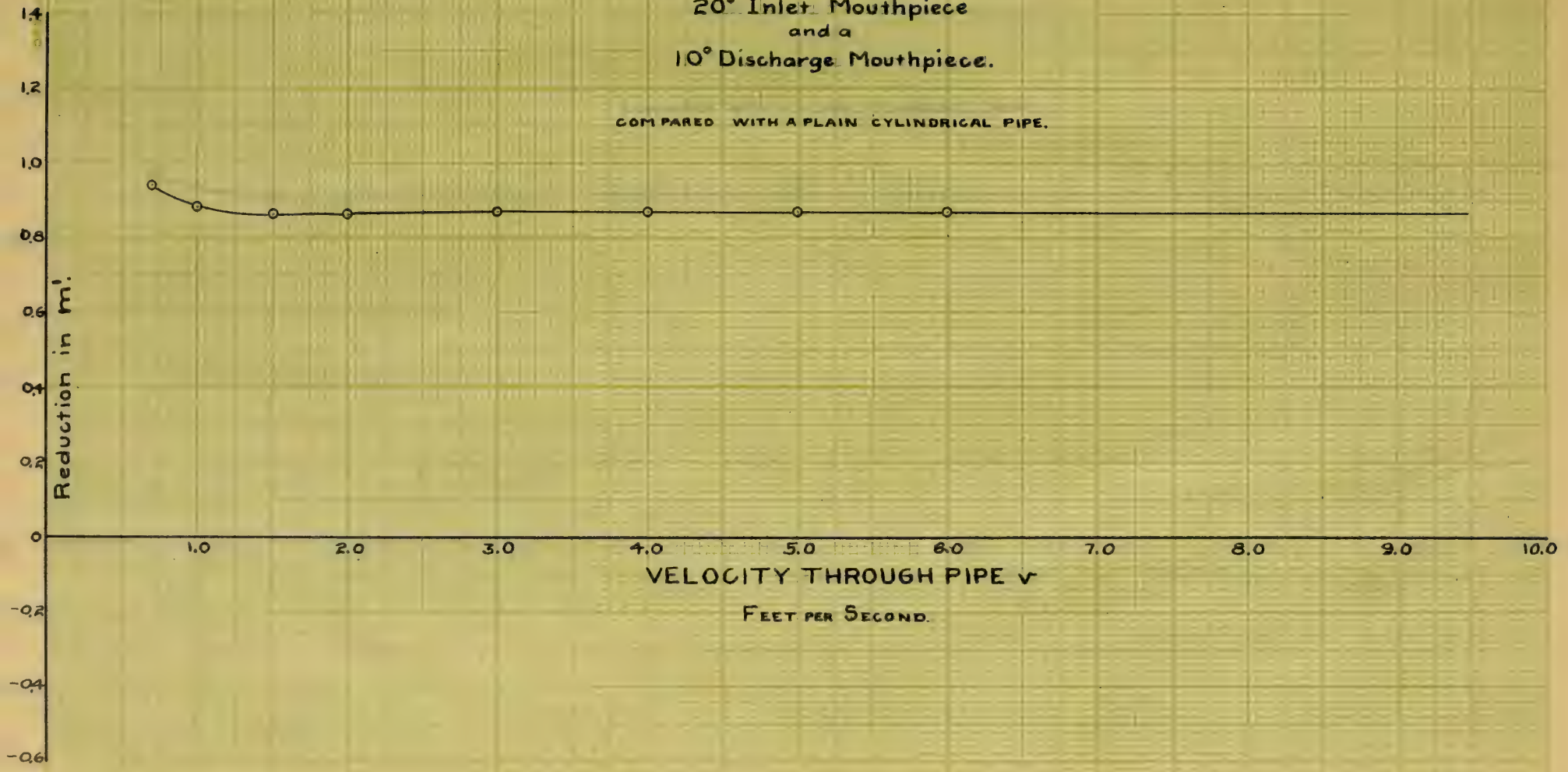


PLATE 29.

Curve Showing Reduction in m' for 6-in. Pipe Due to a 20° Inlet Mouthpiece and a 10° Discharge Mouthpiece.

COMPARED WITH A PLAIN CYLINDRICAL PIPE.

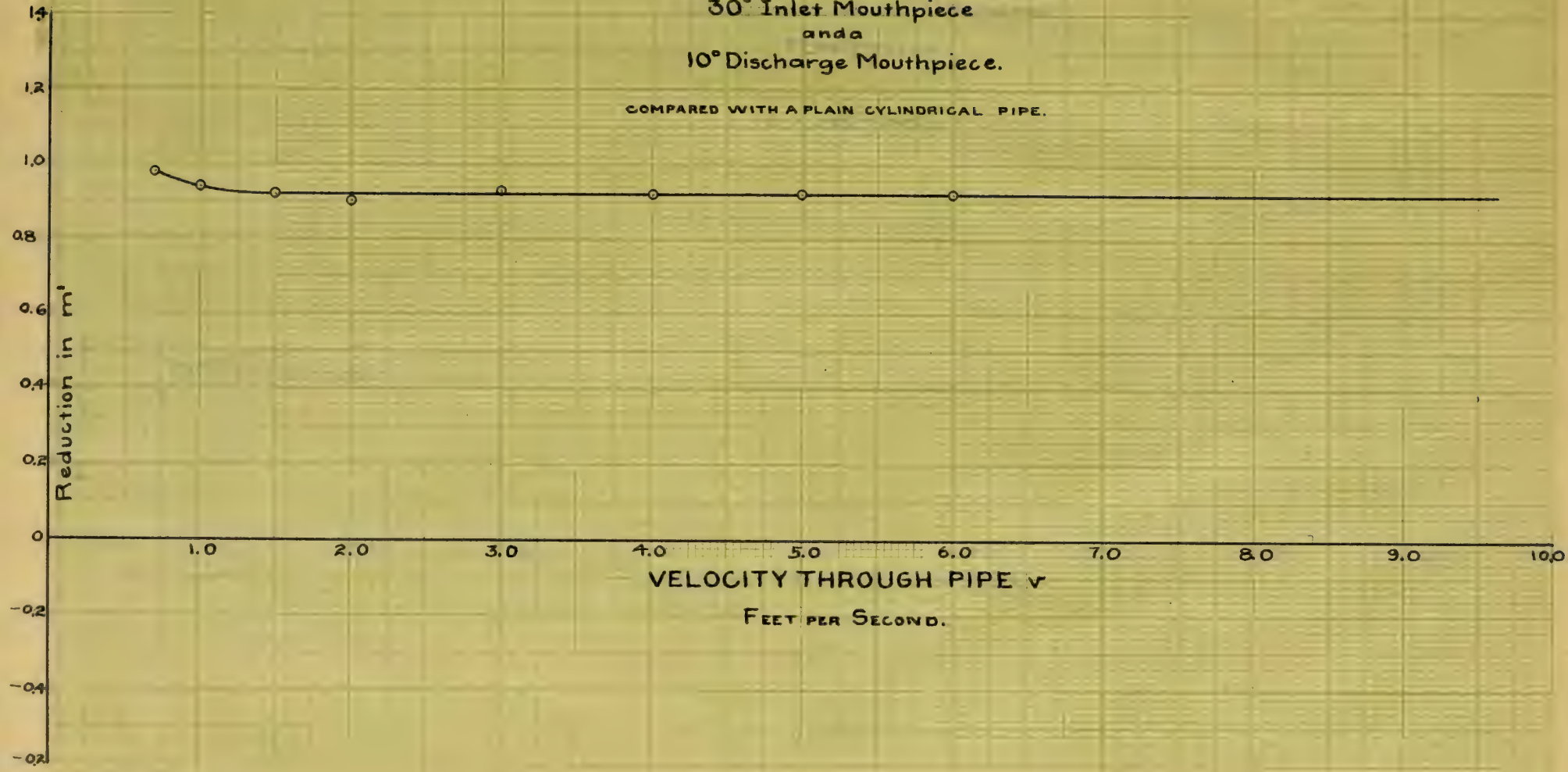


C. C. W. June '04.

PLATE 30.

Curve Showing Reduction
in m' for 6-in. Pipe
Due to a
30° Inlet Mouthpiece
and a
10° Discharge Mouthpiece.

COMPARED WITH A PLAIN CYLINDRICAL PIPE.



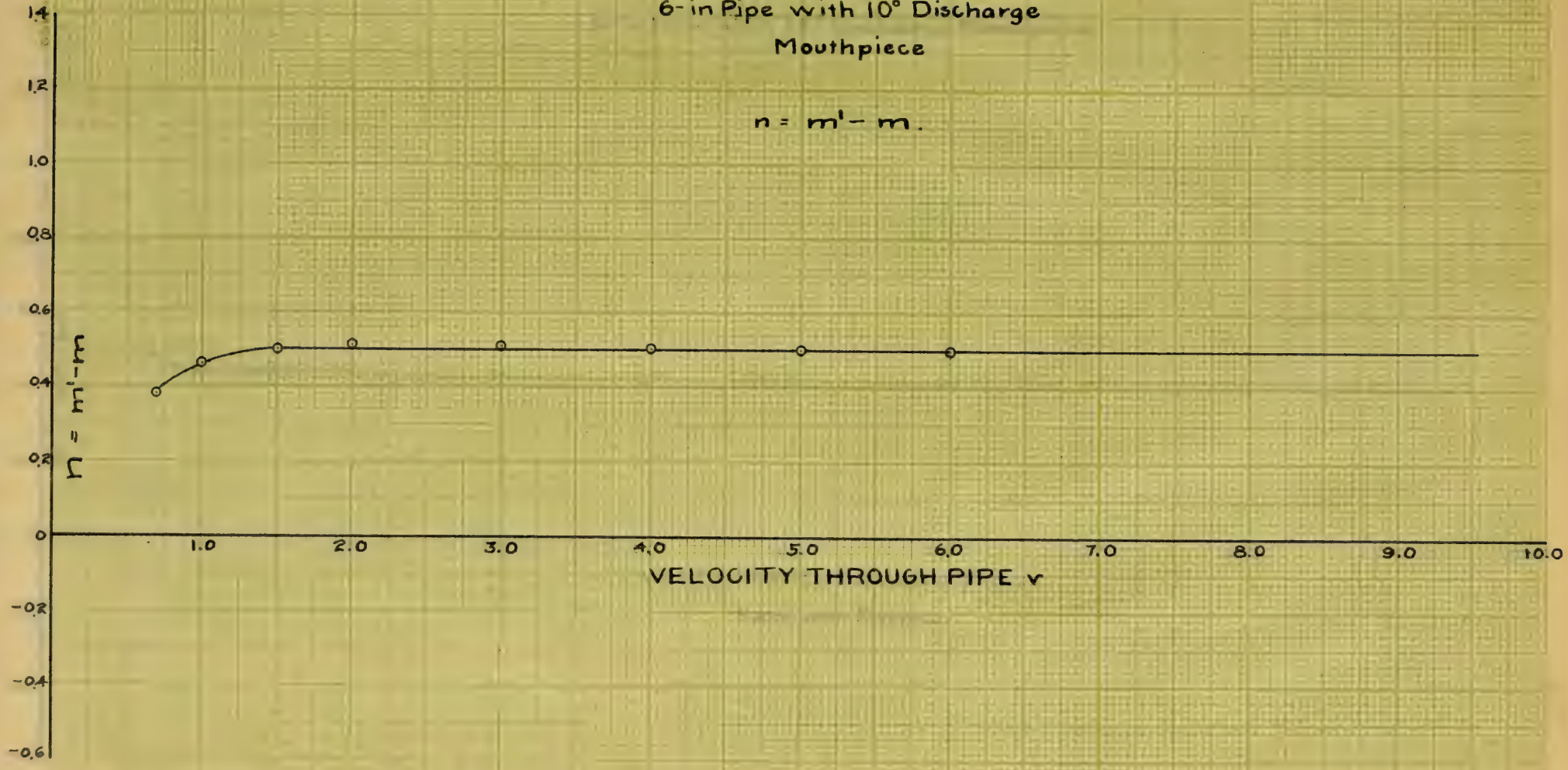
C. C. W. June 1904.

57.

PLATE 31.

Curve Showing Relation
Between v and n
for
6-in Pipe with 10° Discharge
Mouthpiece

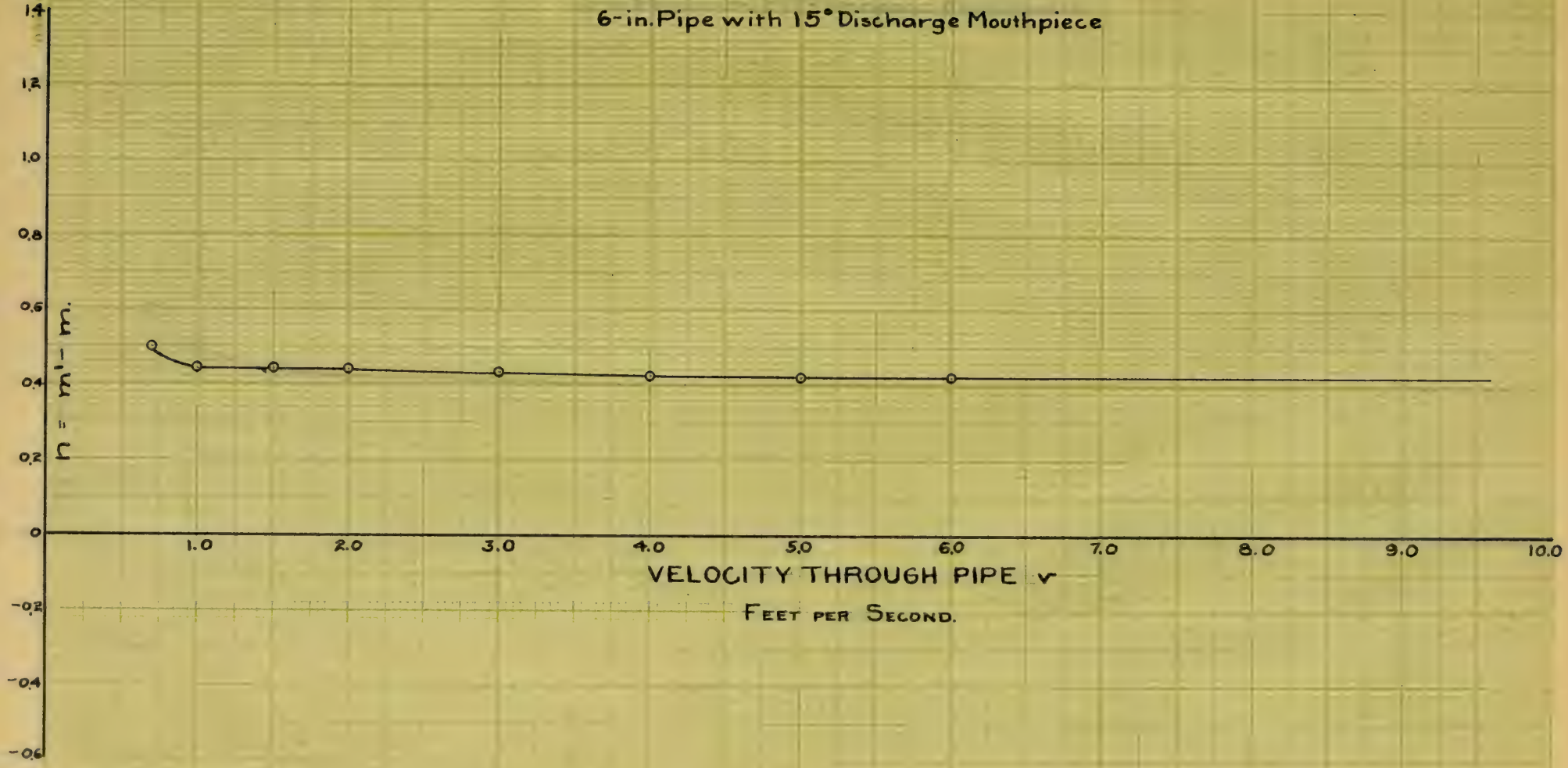
$n = m' - m.$



C. C. W. June '04.

PLATE 32.

Curve Showing Relation
Between v and n
for
6-in. Pipe with 15° Discharge Mouthpiece



C.C.-W. June '04.

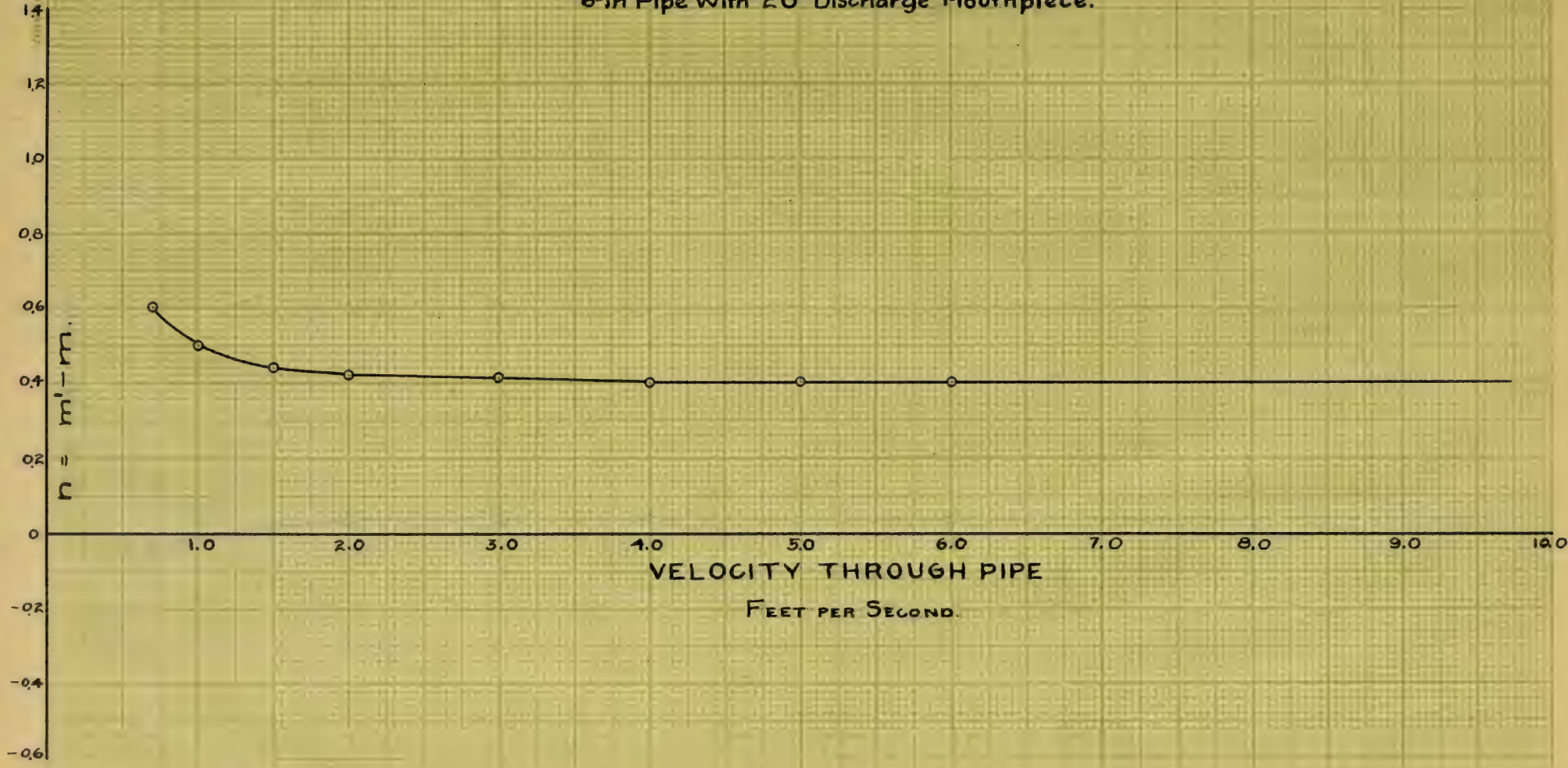
PLATE 33.

Curve Showing Relation

Between v' and n

for

6-in Pipe with 20° Discharge Mouthpiece.



C. C. W. June '04.

69

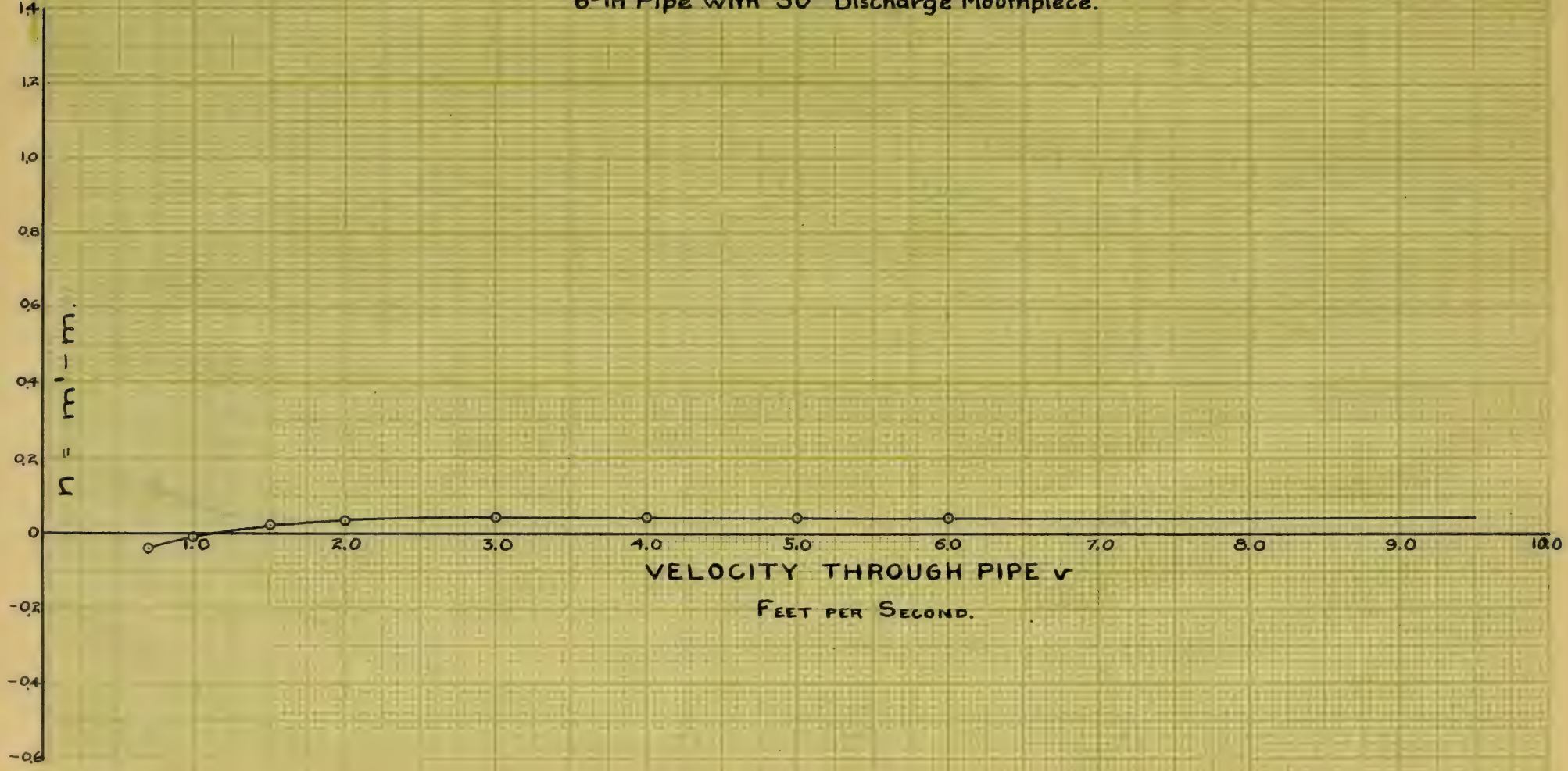
PLATE 34.

Curve Showing Relation

Between v and n

for

6-in Pipe with 30° Discharge Mouthpiece.



C.C. VV. June '04.

61

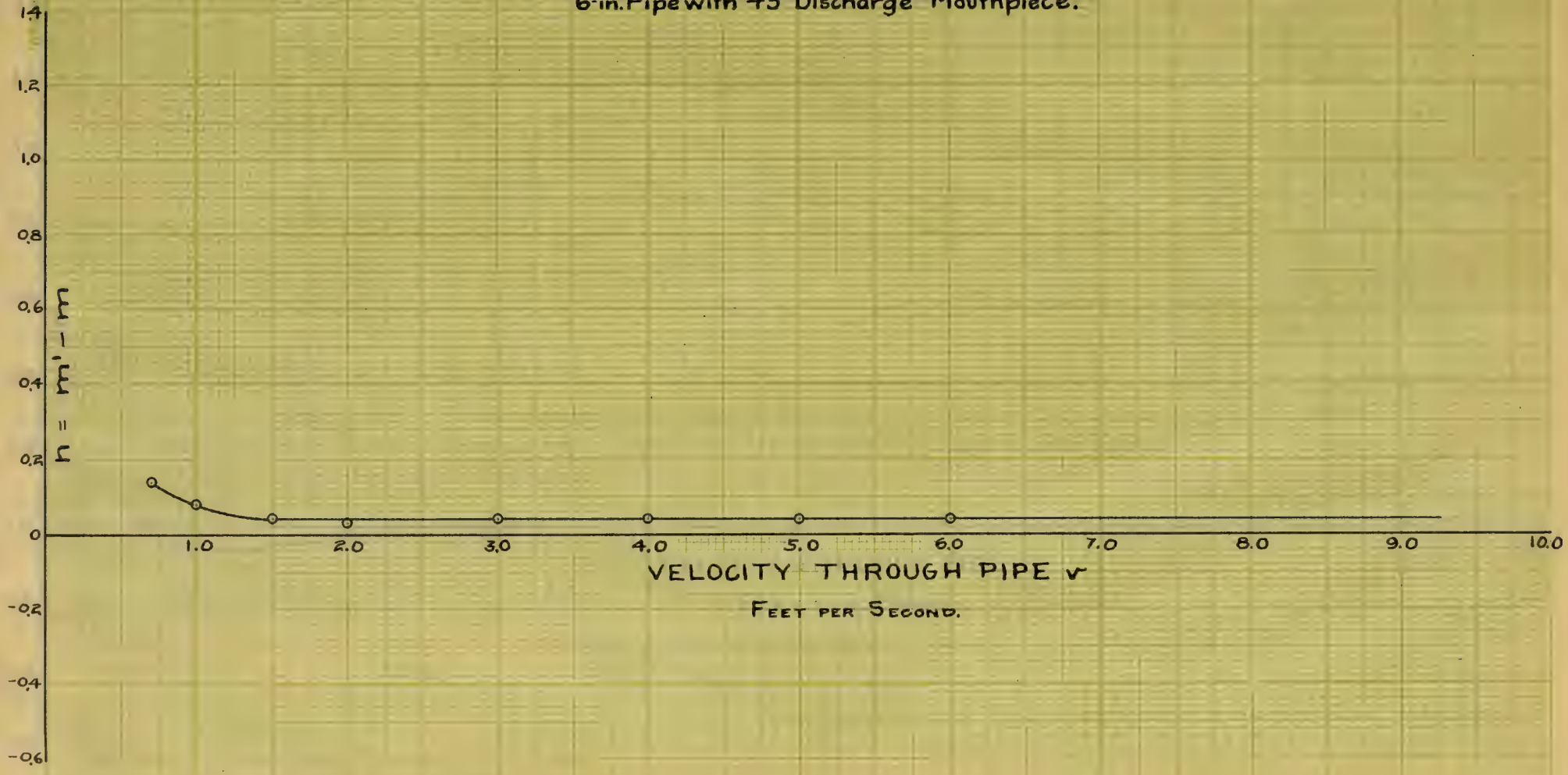
PLATE 35.

Curve Showing Relation

Between V and n

for

6-in. Pipe with 45° Discharge Mouthpiece.

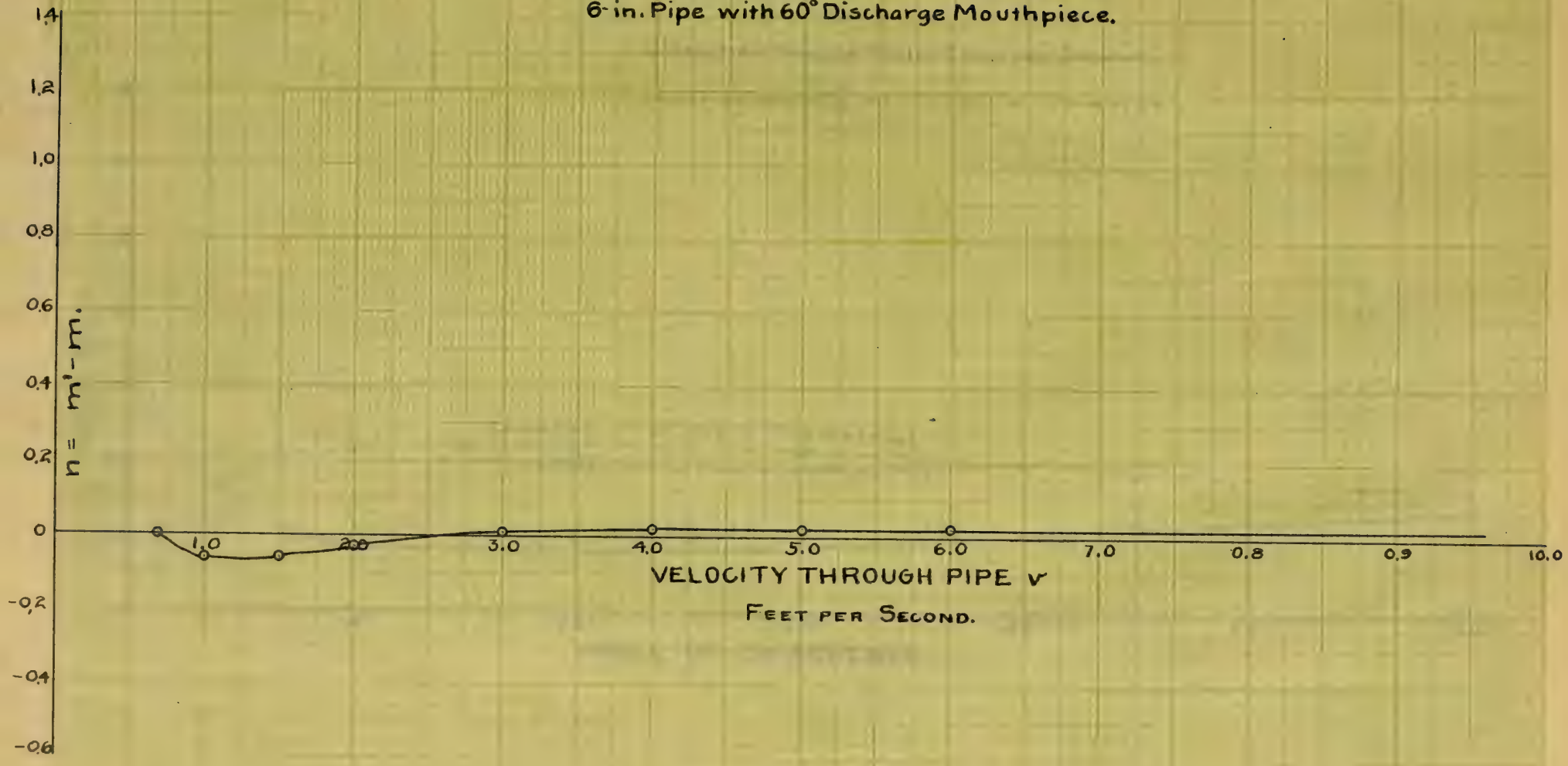


C. C. W. '04.

82.

PLATE 36.

Curve Showing Relation
Between v and n
for
6-in. Pipe with 60° Discharge Mouthpiece.



C.C.W. June '04

PLATE 37.

Curve Showing Amount of Entrance Head.

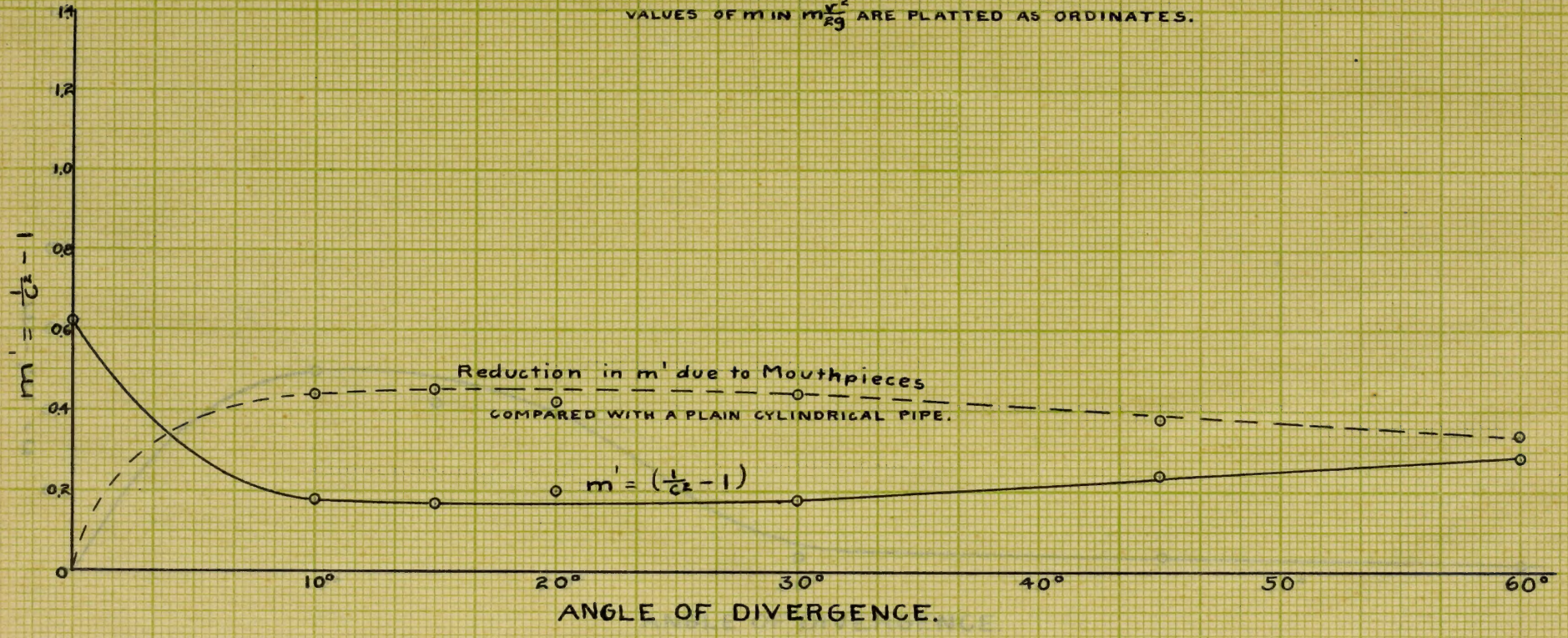
for

Mouthpieces of Different Angles

for

Velocities Greater than 2 feet per Second.

VALUES OF m IN $m\frac{v^2}{2g}$ ARE PLATTED AS ORDINATES.



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